Appendix A
Roseville Creek and Riparian Management and Restoration Plan,
Restoration Strategies and Conceptual Improvement Techniques

1.0 RESTORATION STRATEGIES & CONCEPTUAL IMPROVEMENT TECHNIQUES

This section presents restoration strategies for creeks within the City of Roseville and presents conceptual improvement techniques that may be used to implement these strategies. These strategies and techniques have been selected because they provide an approach to creek management and restoration that supports improvements to multiple resources, specifically water quality, aquatic habitat, wildlife habitat, and channel stability. The degree to which these strategies and techniques are implemented will depend on individual site conditions, specific goals of the restoration project, and commitments that may be made as part of a securing a consolidated permit for Plan implementation.

Table 1-1 lists each recommended strategy and indicates which of these four resource values benefit from implementing the strategy. This table helps to illustrate the fact that restoration decisions intended to address any one aspect of ecosystem health are very likely to impact other aspects of ecosystem function. Thus, any restoration strategy should be implemented with regard for the full range of impacts it may generate, and be designed to maximize its potential for beneficial impacts on as many creek resources as possible.

Table 1-1. Restoration Strategies and Benefits

Strategy	WQ	Aquatic Habitat	Channel Stability	Wildlife Habitat
Revegetation	■	■	■	■
Bank Recontouring	■	■	■	■
Bank Stabilization	■	■	■	■
Channel Realignment		■	■	■
In-stream Structures		■	■	■
Grade Control		■	■	■
Removal of Fish Barriers		■		
Beaver Management	■	■	■	■
Invasive Plant Management		■		■
Runoff Controls	■	■	■	■
Access Management	■	■	■	■

The implementing techniques for each of these restoration strategies were selected based upon a comprehensive review of restoration techniques that have been proven to be successful and the applicability of those techniques to the issues identified in the Pleasant Grove and Dry Creek watersheds. It is important to recognize that the science of creek restoration is continually evolving as more projects are implemented and lessons are learned about how certain techniques perform and respond to varying conditions. Therefore, an adaptive approach to planning for creek restoration and management should be adopted in which the list of available techniques is updated to reflect the best available science.

Techniques are described here at a conceptual level of detail. Prior to implementing any of these techniques, a detailed assessment of site conditions should be conducted by a team with expertise in geomorphology, revegetation, civil and/or geotechnical engineering, and fish/wildlife biology. The specific manner in which techniques are implemented will need to be tailored to each individual site to account for variations in characteristics such as bank slope and condition, creek flow, adjacent land uses, soils, and existing vegetation.

Chapter 5 of this Plan describes the City's creek reaches that were identified through the ECAR as needing the application of restoration strategies, and the specific strategies needed for each reach. The particular technique(s) used to implement the strategy at a given site should be identified following the site assessment described above in order to pick the techniques that are most appropriate for the localized conditions and available resources.

1.1 Revegetation

1.1.1 Benefits

Revegetation of creek corridors provides important benefits in many areas of ecosystem function. Healthy riparian vegetation stabilizes creek banks, helps prevent erosion, provides wildlife habitat, and improves aquatic habitat by shading and contributing vegetative matter to support aquatic macroinvertebrate species.

1.1.2 Where Appropriate

Revegetation should be implemented where any of the following conditions exist:

- Banks are exposed and/or eroding (additional bank stabilization techniques described below may also be)
- After eradication of existing non-native vegetation
- Existing vegetation is sparse, disturbed, and/or lacking structural or biological diversity
- In conjunction with any restoration activity that disturbs vegetation such as bank stabilization or bank recontouring

1.1.3 Standard Practices

When establishing or enhancing riparian plantings, the following standard practices should be incorporated in the planting plans and specifications to increase the likely success of the project.

Plant Selection

- Native plant species should be selected that are consistent with the objectives for the revegetation project. If the project includes a buffer that is intended to intercept surface flow from adjacent land uses it should include dense plantings of grasses or other herbaceous species that stabilize the soil, slow down the flow, and trap sediments. If the buffer is intended to improve habitat, the target type of plant community should provide the basis for developing the planting plan for the buffer. The determination of the type of the species to use in the revegetation project should be made collectively by the project Landscape Architect, Revegetation Specialist, Engineer, and/or Wildlife Biologist when the planting plan is developed.

- Revegetation projects may include plants in a variety of conditions such as bareroot, vegetative cuttings, containerized, balled and burlapped (B&B), plugs, and seed. The type of condition and size to be used depend on time of year, species, available budget, site conditions, and who will perform the planting. The determination of the condition and size of plants to use in the revegetation project should be made by the project Landscape Architect and/or Revegetation Specialist when the planting plan is developed.

- When feasible, purchase or collect plants and seeds that were harvested or grown in the Sacramento or western Placer County area.

Spacing

- Groups of like plants should be interspersed with groups of other species to create a more naturalistic pattern. Trees should be planted in groups of 2-3 with shrubs planted in groups of 3 – 9 between the tree groups.

- Plant densities should be determined using the triangular spacing method because it results in a denser planting area than the square grid method.

- The spacing of individual plants will vary with each site and species. In general, the spacing between plants should increase with the mature size of the plant. For example, species that form a large canopy such as valley oak and California sycamore should be planted further apart than willows or elderberries. Spacing for large trees should range from 10 ft. – 25 ft. on center, with spacing for smaller trees and shrubs being from 5 ft. – 10 ft. on center.

Plan Review

- A plan of the proposed revegetation project should be prepared and reviewed by the City before implementation. The plan should show species, number, condition, bank location, planting method, and irrigation requirements for all plants.

- The project plan should also address specific erosion control measures need to insure that any disturbed soil will be stabilized to prevent soil erosion during the rainy season. Stabilizing methods include mulch, hydroseed, and erosion control blankets. These methods may be used in combination as needed to properly secure the site.

- The proposed planting design should be evaluated by the City's Department of Public Works for consistency with flood control plans.

Site Preparation

- Non-native invasive species should be removed or reduced to the extent feasible to enhance establishment of native species. See discussion in this section on techniques for invasive species management for more information.

- Use manual methods or equipment that exerts low ground pressure whenever possible to accomplish site grading without damaging soil structure.

- If extensive grading by heavy equipment is required to prepare the site, try to limit this activity to the dry season to avoid damaging soil structure.

- If site has become heavily compacted, prepare soil by ripping to a depth of 12" in two perpendicular passes. Smooth to an even grade. This technique may only be used where site grades allow safe operation of the equipment.

- Planting holes should be at least twice the diameter of the root ball with a pedestal in the bottom to prevent root balls from settling below the finished grade.

- Revegetation should occur in native soil with little or nor amendment whenever possible. If topsoil has been lost, it may be necessary to work organic matter and amendments into the soil before planting to improve fertility and drainage. In this situation, a soil analysis should be conducted to determine what, if any, amendments are needed.

Installation

- Make sure that project area is secured from public access to prevent accidents and injury and appropriately signed to inform the public of the project purpose and goals.

- Identify any vegetation adjacent to the project area that is to be protected and provide protective fencing around the critical root zone.

- Harvest any native plants that are to be replanted in the finished project and establish them in a suitable temporary location.

- All plants should be inspected prior to installation to insure they are healthy, free of pests, have good root formation, and are of the proper species. Containerized and B&B stock should be inspected for girdling roots.

- In general, revegetation should occur in the fall shortly before the onset of the rainy season (except bareroot stock and dormant cuttings as noted below). This will reduce the amount of supplemental irrigation required during the first 6 months of the plants' establishment period. This is also the time of year when most plant species are entering dormancy or a period of slower growth, and the stress associated with transplanting is better tolerated.

- It is preferable to have all planting completed with the onset of the rainy season to avoid exposing disturbed soil to the erosive forces of the rain. If it becomes apparent that it will be necessary to plant during the rainy season, the site should be seeded with a native erosion control grass mix in late September or early October to stabilize the site as much as possible. Soil disturbance at planting time should be limited to the minimum necessary to install plants, and disturbed areas should be mulched when planting is completed.

- Bareroot stock should be planted while it is fully dormant, typically between December and early February. Cuttings should be collected and planted during this same time frame since they will be dormant and more likely to survive the transplant stresses.

- When planting containerized or B&B stock, the root crown should be at or slightly above (1/2") the soil surface after planting, settling, and irrigation. Build a berm around the plant to create an irrigation basin with a minimum diameter of 3 times the diameter of the rootball and cover the area with 2"-3" of biodegradable mulch.

- Water all plants thoroughly immediately after planting.

- Vegetative cuttings may require some form of pretreatment, such as soaking or application of a rooting hormone to encourage root development. Always plant cuttings so that at least three nodes are below the surface.

Plant Protection and Irrigation

- Measures such as cages, root protection baskets, tree shelters with wire covers, and/or trunk wrapping should be incorporated into the revegetation project to protect young plants from browsing by species such as voles, deer, rabbits, and beaver. The type of measure to be used should be determined in consultation with the project wildlife biologist and installed per the manufacturer's specifications. All protection measures need to be carefully removed before they constrict plant growth and disposed of offsite. Replacement protective measures may need to be installed if the plant is still small enough to be susceptible to predation or other threats.

- A wooden stake at least 14" tall should be placed nest to all plants to make their locations visible for future monitoring and maintenance.

- Supplemental soil moisture may be required during an establishment period until plants have developed sufficient root mass and are adapted to naturally available moisture. Three years is a reasonable period for maintaining supplemental irrigation, but a longer time may be needed if plants are growing slowly and/or annual variations in climate are unusually extreme.

- The type of irrigation (drip, bubblers, hand watering, etc.) should be determined by the project Landscape Architect/Revegetation Specialist to reflect site conditions, such as proximity to a public water supply, access to the site, moisture requirement of the plants, and anticipated establishment period. In no case should irrigation result in overspray or surface runoff.

- If a gel-type soil wetting agent is used instead of traditional irrigation, the product may need to be replaced every few months after the effectiveness diminishes.

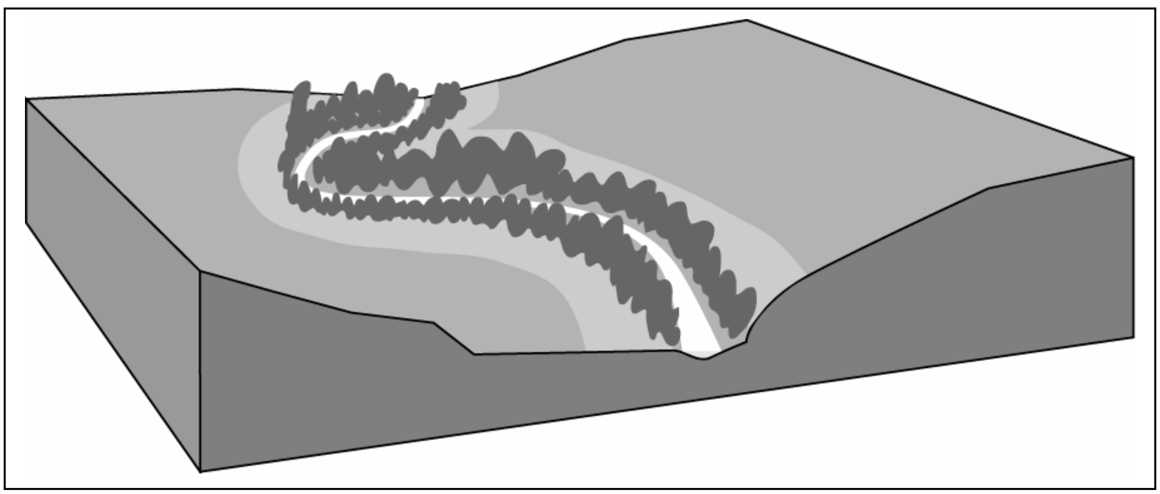
1.1.4 Techniques

Vegetative Buffers

A vegetative buffer is a band of vegetation (trees, shrubs and herbaceous plants) between a waterway and an adjacent land use. In addition to benefiting water quality, vegetative buffers and swales provide habitat opportunities for terrestrial species that live, forage or breed in riparian areas where seasonal fluctuating water levels and high groundwater tables support a diverse community of vegetation. Riparian zones provide habitat for up to 80 percent of wildlife species in the west[1].

Riparian buffers should be wide enough to reduce the amount of pollutants and sediment in overland stormwater runoff and to provide some interior habitat for species that are intolerant of human activity. While exact requirements for adequate buffer widths have not been established, current City of Roseville General Plan policies specify the preservation of the 100-year floodplain and contiguous areas in excess of the 100-year floodplain as merited by special resources or circumstances. These special circumstances may include sensitive wildlife or vegetation, wetland habitat, oak woodland areas, grassland connections in association with other habitat areas, slope or topographical considerations, etc. In areas where preservation of the 100-year floodplain results in a buffer of less than 100 feet on each stream bank for perennial streams, opportunities should be sought for preservation to increase the size of these buffers.

Figure 1-1. Riparian Buffer Diagram



Increasing Vegetation and Structural Diversity

One of the primary goals of riparian restoration is to increase the diversity of vegetation species and structure to meet the lifecycle needs of a greater number of mammals, reptiles, amphibians, birds and other terrestrial riparian species. Species diversity describes the variety of native plant species found within an area of vegetation that is relatively uniform in composition. Canopy or structural diversity refers to the presence or absence of three canopy layers: a tree or overstory, a shrub or understory, and an herbaceous layer. A healthy riparian zone should have all three canopies well represented, with plant material at various stages of development in each.

The recommended way to increase species and structural diversity is through a coordinated approach that includes the following three components.

[1] Riley, 1998.

1. Remove non-native vegetation to create a more favorable condition for a variety of native species to become established. (See1.9 Invasive Plant Management below)

2. Plant native riparian tree, shrub and herbaceous species consistent with the naturally occurring vegetation community for the site. The CNPS Manual of California Vegetation classifies vegetation communities according to the dominant species within the community. CNPS series associated with Plan area are listed in table Table 1-2. Each series includes a list of commonly associated species and should be used as the basis for developing a planting palette for a particular site. Where native vegetation is already partially established, consider planting species to augment a missing or sparse canopy layer or to increase species diversity.

3. Manage riparian vegetation to prevent reestablishment of non-natives and to increase species and structural diversity. Specific creek corridor vegetation maintenance methods are described in Chapter 6.

Table 1-2. CNPS Series for Roseville Watersheds

Watershed Location	Dominant Species for CNPS Series
Upper Pleasant Grove[2]	Mixed Willow (*Salix spp.)* Fremont Cottonwood *(Populus fremontii)* Spikerush (*Eleocharis spp.*) Cattail *(Typha latifolia)* Arroyo Willow (*Salix lasiolepis*)
Lower Pleasant Grove[3]	Interior Live Oak *(Quercus wislizenii)* Valley Oak *(Quercus lobata)* Mixed Oak Fremont Cottonwood *(Populus fremontii)* White Alder *(Alnus rhombifolia)*
Dry Creek[4]	Blue Oak *(Quercus douglasii)* Fremont Cottonwood *(Populus fremontii)* Interior Live Oak *(Quercus wislizenii)* Mixed Willow (*Salix spp.)* Valley Oak *(Quercus lobata)* White Alder *(Alnus rhombifolia)* Fremont Cottonwood *(Populus fremontii)*

Snag Management

Dead trees or snags should be allowed to remain standing as long as they are not a threat to public safety because they provide important shelter, nest and/or forage opportunities for riparian species such as raptors, woodpeckers, owls, and kingfishers.

[2] Foothill Associates, 2003.
[3] Foothill Associates, 2003.
[4] ECORP, 2003.

Where feasible, large snags of 15" diameter at breast height and larger should be left standing for bird habitat. Smaller snags, which may pose a greater threat to fire safety, should be evaluated for their habitat potential prior to removal. The number and density of snags to be left standing should be determined for each site by a qualified biologist with consideration for the habitat needs of the existing or anticipated resident species.

Riparian Corridor Connectivity

When planning for revegetation projects, sites should be selected that have the potential to enhance the connectivity of habitat opportunities within the corridor. If reaches adjacent to a proposed restoration site are in good condition, the project will provide a connection between the adjacent reaches and improve the overall habitat value of all three reaches. If the adjacent reaches are in poor condition, the restored reach will function as either a habitat 'island' or a 'link'.

A habitat island is a small, isolated patch having desirable habitat characteristics. While an island may provide valuable habitat for birds, it is less desirable for other terrestrial species since they are unprotected as they travel through uncovered areas to reach the resources found in the island. Islands should be made as large as possible since their habitat value increases proportionally with size.

A habitat link differs from an island in that it is located in close proximity to other reaches with similar habitat conditions. Terrestrial species may then use the link as a sort of stepping stone to move through the creek corridor, with minimal exposure. In general, creating habitat links will result in greater overall habitat value for the creek system than creating small, isolated habitat islands.

1.2 Bank Recontouring

1.2.5 Benefits

Bank recontouring is the practice of modifying the profile of a creek bank to create a less steep interface between the creek and the bank to reduce average velocities and shear stresses, and reestablish frequent overbank flows across a wider floodplain. Terraces may be introduced that are similar to those found along natural waterways and support a diversity of hydrologic regimes for vegetation growth. Increasing riparian vegetative diversity also improves habitat for riparian species. Bank recontouring can be used for prevention and remediation of bank erosion, stabilizing the channel, and/or increasing channel capacity.

When widening of the channel increases the capacity of the channel to carry floodwater, additional woody vegetation can grow within the channel and large woody debris (LWD) can remain without compromising the floodwater capacity. The increased vegetation provides additional habitat for riparian and aquatic species and permits the growth of trees and shrubs at the water's edge, which shades the surface of the water, provides sheltering habitat for fish, and contributes to aquatic food sources. Additionally, woody vegetation within the channel can slow the downstream flow of floodwater.

1.2.6 Where Appropriate

Bank recontouring should be considered where any of the following conditions exist:

- Bank face angle is in excess of 3:1 horizontal to vertical and is showing evidence of erosion

- Flows are constricted and causing flood management problems

- Creek is undercutting bank and/or bank is collapsing

- Channel has become so incised that riparian vegetation is becoming stranded above level of available soil moisture

- Increased flows are causing channel to migrate laterally and eroding banks in the process of establishing a new channel

- Riparian vegetation lack species diversity due to absence of floodplain terraces

- Surface flow from adjacent land uses is causing head cutting at the bank edge

- Surface flow from adjacent land uses requires additional vegetative filtering or flow velocity controls

1.2.7 Standard Practices

All bank contouring projects, regardless of their magnitude, require certain standard implementation practices.

<u>Planning</u>

- All bank recontouring projects should include a revegetation component since the disturbance associated with bank contouring will destroy the riparian vegetation on the site. (See 1.1 Revegetation above.)

- When designing the recontouring project consider if some form of bank stabilization beyond revegetation is needed. (See 1.3 Bank Stabilization below.)

- A bank contouring project must include a hydraulic study to determine the best configuration of the bank given the hydraulic forces of the stream. Bank contouring is often done in combination with channel realignment projects to reintroduce meander bends and a more ecologically stable channel condition.

- Before a bank contouring project is undertaken, a hydrologic study must be performed to assess the impact of the new channel configuration on floodwater conveyance in the regional stormwater system.

- Identify how any required flow diversion will be handled and the period of time the diversion will be required. Make sure to address hydraulic impacts of the flow diversion approach to prevent erosion and damage to the channel, and any potential impacts to aquatic species. The decision as to the type of flow diversion method(s) to be used should be made by the project engineer, aquatic biologist, and geomorphologist in consultation with the City's Public Works department.

Plan Review

- A plan of the proposed bank recontouring project should be prepared and reviewed by the City before implementation. The plan should include the extent of the project, description of impacts to existing vegetation, timing, plan views and cross sections of the proposed grade changes, cut and fill calculations, diversion strategies, the results of any hydraulic/hydrologic analyses, specific erosion control measures, and information on any stabilization or revegetation techniques included in the project.

Installation

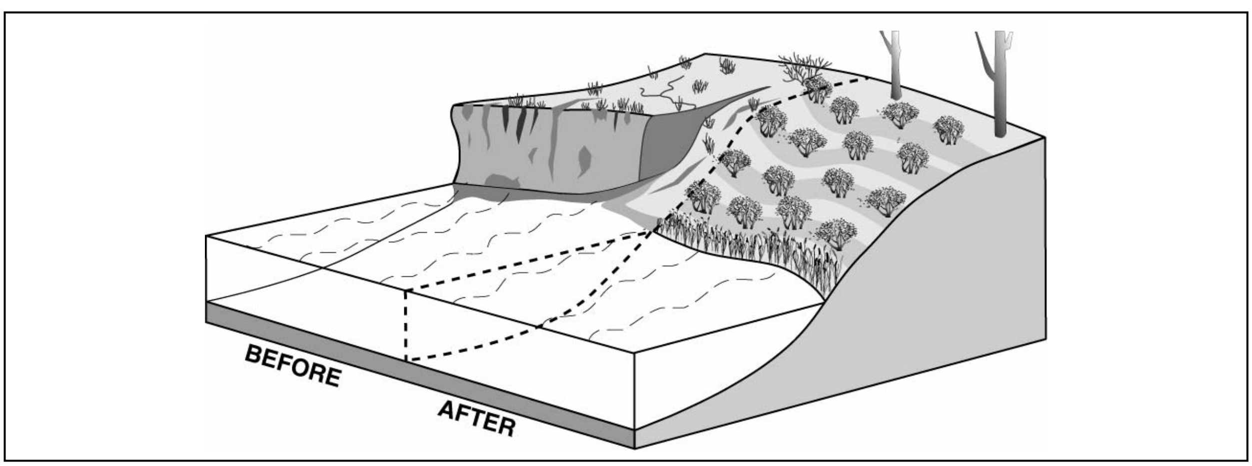
- Make sure that project area is secured from public access to prevent accidents and injury.
- Identify any vegetation adjacent to the project area that is to be protected and provide protective fencing around the critical root zone.
- Harvest any native plants that are to be replanted in the finished project and establish them in a suitable temporary location.
- Stockpile topsoil to be redistributed on finished grade.
- Implement bank protection and stabilization such as erosion control fabric, geotextile materials, willow wattles, or hydroseeding to prevent erosion both during construction and until newly installed plantings are established.

1.2.8 Techniques

Laying Back Banks

Bank contouring that involves relatively moderate changes to the bank profile is also known as laying back the banks. In these types of projects, the ordinary low-flow channel often not modified. Laying back creek banks involves reshaping the banks to a more gradual slope, and may include the introduction of several small terraces that correspond to different flood stage elevations and vegetative communities. As the bank is laid back, the erosive potential of the creek is decreased because water can spread out over a greater area thus reducing velocity and associated sheer stresses. This technique is effective for addressing localized erosion or habitat issues along isolated reaches.

Figure 1-2. Laying Back Creek Bank Cross Section



Floodplain Restoration

Floodplain restoration is a method of bank contouring that involves much more extensive corridor changes than simply laying back the creek banks. The intent of floodplain restoration is to reconnect the channel to the larger floodplain. It may be implemented in conjunction with a channel realignment technique (see 1.4 Channel Realignment below).

Floodplain restoration can only be implemented where access to sufficient open space is available. Floodplain restoration may involve physically modifying the channel to create terraces that can flood, or it may involve removal or relocation of levees. The primary goals of floodplain restoration are to increase the carrying capacity of the creek channel, reduce average velocities and shear stresses, and reestablish frequent overbank flows across a wide floodplain and/or series of riparian terraces.

Separate terraces may be created for the bankfull channel, the 2 to 10-year floodplain and the 10 to 100-year floodplain. The low-flow channel carries the dry-season flow, and frequent floods use the 2-year terrace. Larger flood events will utilize the successively larger terraces with the 100-year flood occupying the full width of the channel. Floodplain restoration can also be designed to provide backwater and emergent wetland habitat during the winter.

1.3 Bank Stabilization

1.3.9 Benefits

Bank stabilization is one of the most critical creek restoration and management strategies for the City of Roseville as creek flows increase in magnitude and duration due to development. Bank stabilization is directly tied to the protection of property, public safety, erosion, and the quality of aquatic and wildlife habitat.

1.3.10 Where Appropriate

Bank stabilization should be considered where any of the following conditions exist:

- After eradication of existing non-native vegetation and simple planting or seeding as described in section 1.1 Revegetation above will not adequately address erosion
- A bank recontouring project results in banks that cannot be stabilized by simple planting or seeding as described in section 1.1 Revegetation above
- Bank slopes are in excess of 3:1 horizontal to vertical and cannot be flattened through recontouring due to adjacent land use constraints or the need to avoid impacts to valuable riparian vegetation
- Hardscape armoring needs to be removed to improve habitat, aesthetics, and/or channel hydraulics
- Surface flow or outfall discharges are eroding the creek bank
- Banks are exposed and/or eroding for any reason

1.3.11 General Practices

A wide variety of techniques are available to prevent bank erosion, and research into new methods and products is ongoing. However, there are some general practices that should be incorporated into the planning and design of any bank stabilization project.

Planning

- The right stabilization technique(s) must be selected for the particular hydrologic conditions of the project area. Different stabilization techniques are generally required to address erosion related to surface flow from adjacent land uses versus erosion resulting from creek flows.

- Multiple techniques may be required to provide both immediate and long term stabilization, and to stabilize all sections of the slope profile. Decisions about which techniques to use should be made by the project engineer and geomorphologist in consultation with the City's Public Works department.

- Bank stabilization projects should include an evaluation of the potential for downstream hydraulic impacts and of the localized hydrologic conditions.

- If bank stabilization projects involve plant materials, determine if supplemental irrigation will be needed, how it will be delivered, and for what period of time.

- Identify how any required flow diversion will be handled and the period of time the diversion will be required. Make sure to address hydraulic impacts of the flow diversion approach to prevent erosion and damage to the channel, and any potential impacts to aquatic species. The decision as to the type of flow diversion method(s) to be used should be made by the project engineer, aquatic biologist, and geomorphologist in consultation with the City's Public Works department.

- If the bank stabilization technique(s) selected don't result in revegetation, include a vegetative element whenever possible to increase habitat value and mitigate aesthetic impacts.

- Consider whether bank contouring and/or channel realignment may be needed in conjunction with bank stabilization to achieve the greatest long term benefit.

Plan Review

- A plan of the proposed bank stabilization project should be prepared and reviewed by the City before implementation. The plan should include the extent of the project, description of impacts to existing vegetation, timing, plan views and cross sections of the proposed stabilization techniques, diversion strategies, the results of any hydraulic/hydrologic analyses, and specific erosion control measures to be implemented during the construction phase.

Installation

- Where bank erosion presents an imminent threat to property and/or public safety, the use of temporary hardscape stabilization techniques may be required. A strategy should be developed for replacement of these techniques with a more ecologically appropriate technique when/if the imminent threat passes.

- Proper anchoring of stabilization materials is necessary to prevent dislodgement of materials that could cause flow obstructions, injuries to wildlife, hydraulic impacts, or downstream hazards. The project engineer and geomorphologist should identify anchoring methods.

- Make sure that project area is secured from public access to prevent accidents and injury.

- Identify any vegetation adjacent to the project area that is to be protected and provide protective fencing around the critical root zone.

- Harvest any native plants that are to be replanted in the finished project and establish them in a suitable temporary location.

- Stockpile topsoil to be redistributed on finished grade.

1.3.12 Techniques

<u>Biotechnical Stabilization</u>

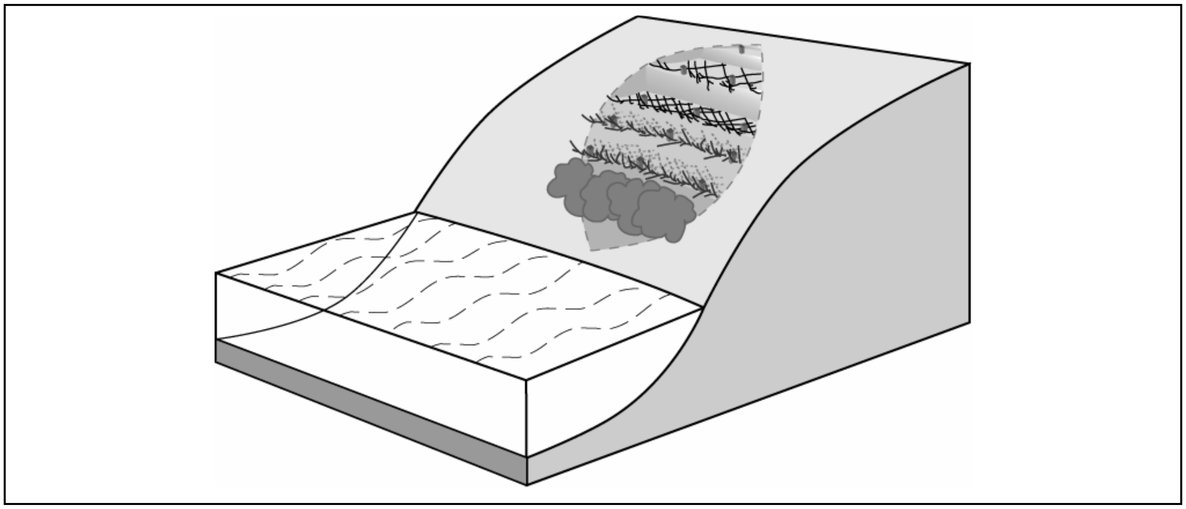
Biotechnical techniques for bank stabilization utilize plant materials to create an erosion control structure. Woody plants such as willows, buttonbush, coyote bush, alders, ash, box elder, and cottonwoods provide dense networks of roots that hold soils together. Herbaceous plants such as sedges and rushes also provide erosion protection, but limited slope stability. These types of native plants tolerate frequent inundation over long periods of time and therefore are appropriate for the water's edge. In addition to their ability to hold soils together, thick mats of vegetation near the bank tend to increase roughness and produce a boundary layer of slower water, reducing the potential for bank erosion. When overtopped, many of these plants lean over, limiting their overall effect on water surface elevations.

Biotechnical methods for bank stabilization also enhance creek corridor habitat values because the resultant vegetation provides shelter, food, and nesting opportunities. The vegetation provides shade over the surface of the creek, which lowers summertime water temperatures and creates overhanging root masses for fish shelter.

The following biotechnical methods of biotechnical stabilization are appropriate for application in the Roseville Creek corridors.

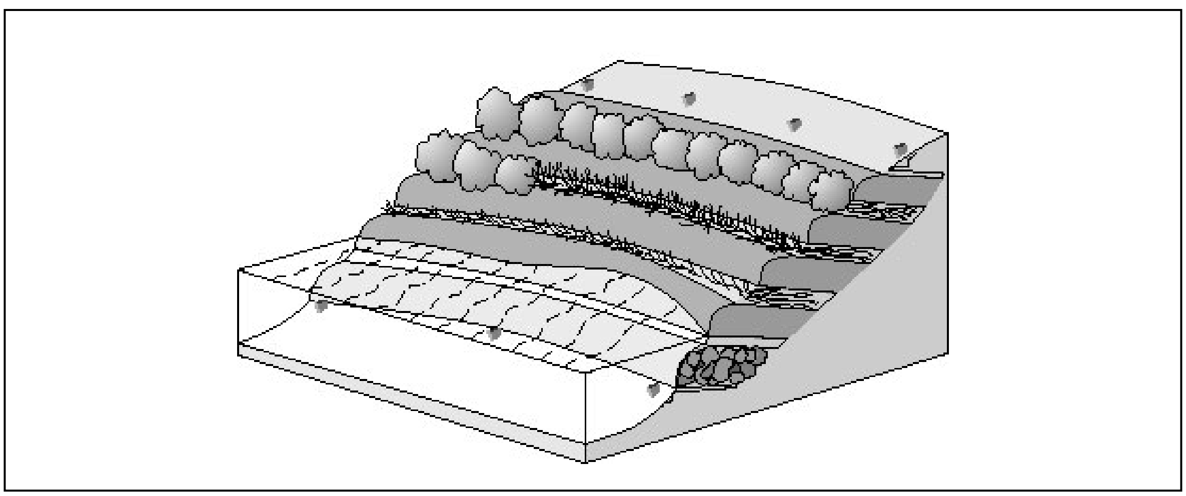
- **Brush Packing**: Alternating layers of live branches and compacted soil are incorporated into a washed out bank to repair a small slump or gully not larger than 4 feet deep or 4 feet wide.

Figure 1-3. Brush Packing



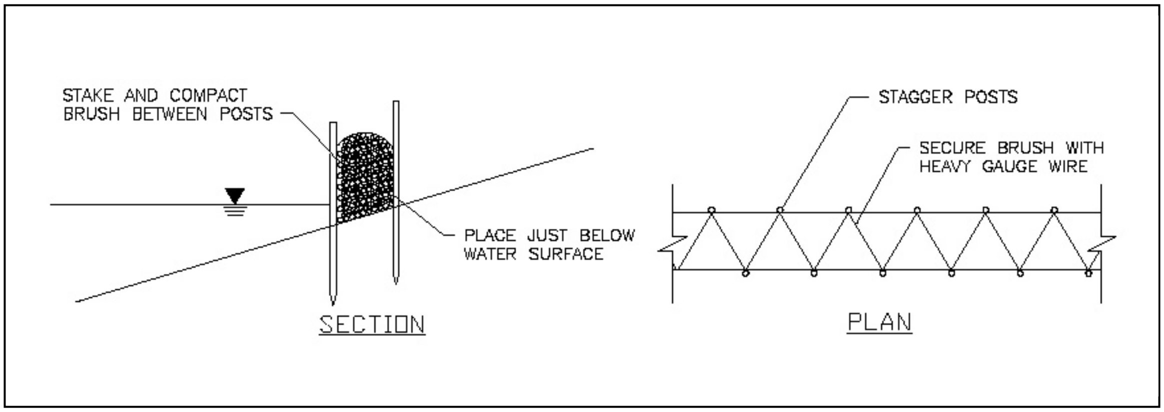
- **Brush Layers:** Brush layers (or vegetated geogrids) are very similar to branch packing except that the technique is applied across the entire face of a bank to be stabilized. The cut ends of live branches are inserted into bank terraces with just the tops extending approximately 12 inches beyond the surface of the slope. Each terrace typically consists of 3 layers of branches separated by 3 - 5 inches of soil between each layer. The next terrace is built by placing 3 - 5 feet of soil on top of the first terrace and sloping it back to meet the design grade. Soil layers may be wrapped in a biodegradable blanket for additional erosion protection. Brush layers are best used on slopes with 2:1 horizontal run to vertical rise or flatter.

Figure 1-4: Brush Layers



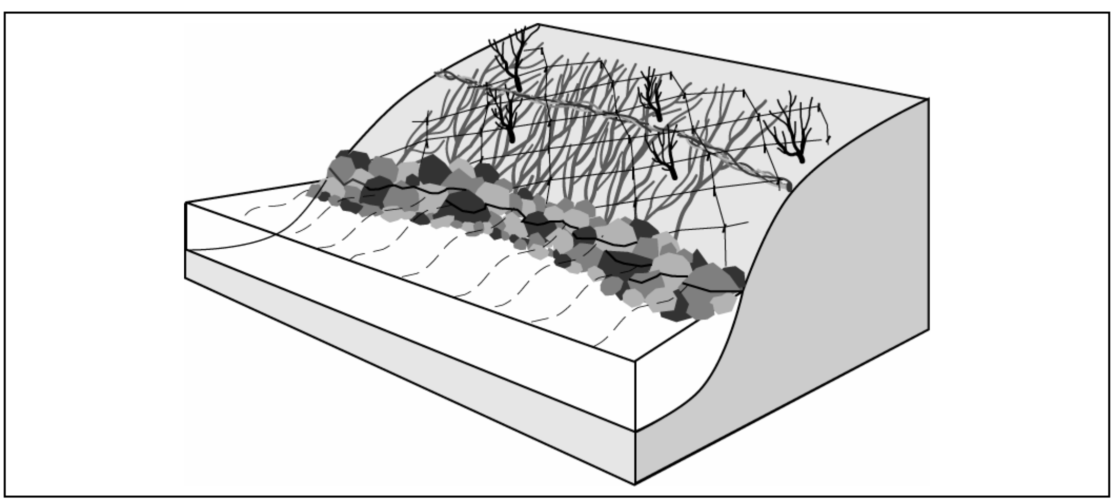
- **Brush Boxes**: Compacted piles of brush cuttings are stacked between parallel rows of stakes located on the bank right at the creek's edge. The stakes are secured with heavy wire to maintain the rigidity of the structure. Brush boxes trap sediment from surface flow, protect the bank from stream sheer stresses, and optimize establishment of vegetation by maintaining contact between cuttings and moist soil. However, stakes and wire should be removed once vegetation is established to prevent it from entering the channel or injuring wildlife.

Figure 1-5. Brush Boxes



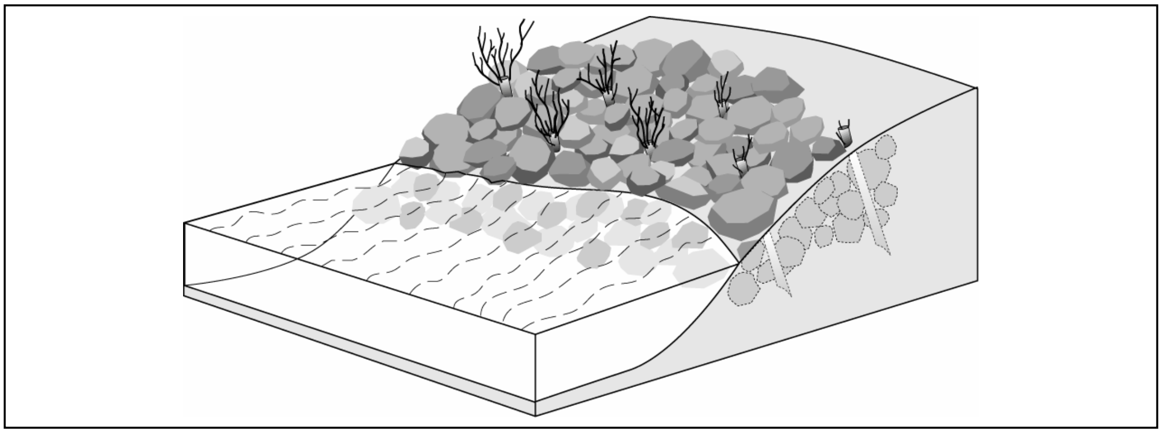
- **Brush Mattresses**: A combination of live stakes, live fascines and/or dormant branch cuttings are laid over the creek bank and secured with a grid of stakes and wire or rope to provide immediate cover and to eventually take root in the slope. Good soil contact is important for the success of this method so additional soil is placed on the mattress and worked down into the spaced between the plant materials. Since this method is applied to the slope above base flow levels, additional protection for the slope toe may required. Brush mattresses are suitable for protecting 2:1 horizontal run to vertical rise or flatter banks from the erosive forces of both creek and surface flows but are not appropriate for slopes experiencing mass movement. The mattresses can be constructed around larger plants. Wire and/or rope needs to be anchored and removed once plantings are established. Since dormant cuttings are used this techniques must be installed in the late fall or early winter.

Figure 1-6. Brush Mattresses



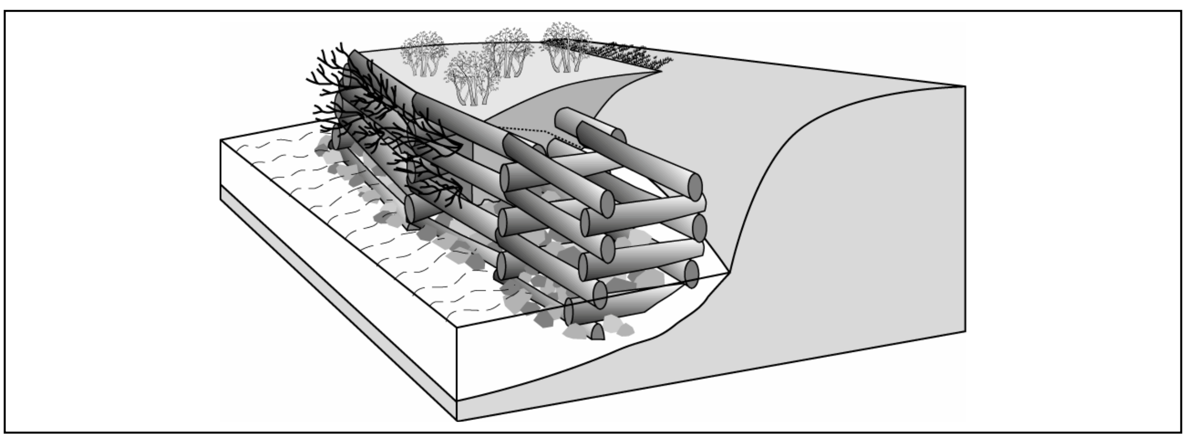
- **Joint Plantings**: Live stakes are inserted into the creek bank in the spaces between rock rip-rap to facilitate establishment of a root mat underneath the rock and to improve the aesthetic and habitat value of the rip-rap. Planting collars should be used to protect plant tissue from damage and abrasion.

Figure 1-7. Joint Planting



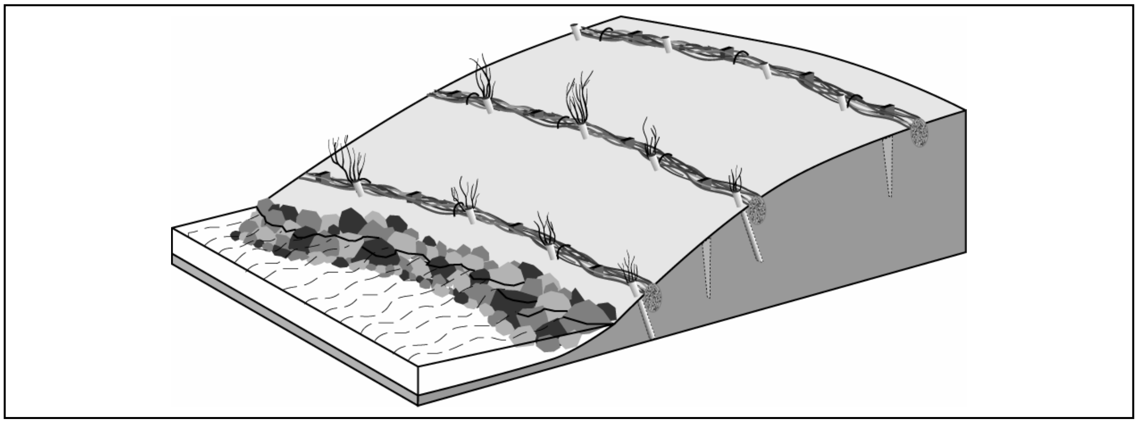
- **Live Cribwalls**: Untreated logs or timber members made from rot resistant species are constructed into interconnecting boxes situated above the base flow level and filled with alternating layers of soil and live branch cuttings. Root wads may also be incorporated into the structure. This method is relatively expensive but provides immediate structural stability for nearly vertical banks and accelerates the establishment of woody species.

Figure 1-8. Live Cribwalls



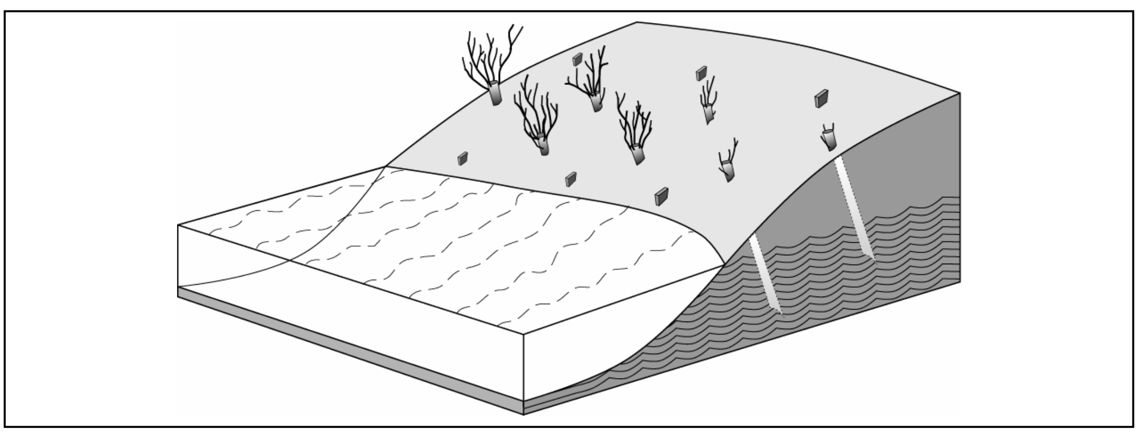
- **Live Fascines/Wattles**: Bundles of long, straight dormant branch cuttings (typically willow or alder) are bound together with wire or twine in cylindrical bundles about 6-8 inches in diameter and 8-10 feet long. The bundles are placed in shallow trenches parallel to the slope of the bank and staked into place with live or dead stakes. This technique is best used on slopes of 2:1 horizontal run to vertical rise or flatter, and is intended mainly to address erosion related to surface flow. Since dormant cuttings are used this techniques must be installed in the late fall or early winter.

Figure 1-9. Live Fascine/Wattles



- **Live Stakes**: Living woody plant cuttings from willow or other riparian species are tamped into the ground and eventually take root. Stakes must have access to soil moisture to root and be long enough so that several nodes are underground. This is a relatively inexpensive method that does not require significant site disturbance. Live stakes can also be used to pin down surface erosion control materials. Slope should be 2:1 horizontal run to vertical rise or flatter. Slope toe protection may be required. This technique can be used where creek flows are slow with relatively little shear stress.

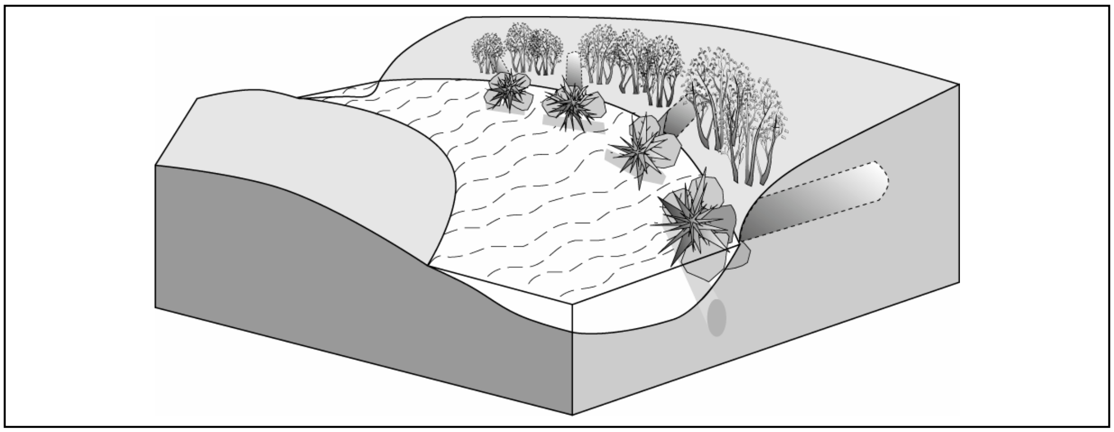
Figure 1-10. Live Stakes



- **Live Cutting Fences**: This technique is similar to the live stake method (described and illustrated above) except that the cutting are installed parallel to the contours at intervals several feet apart to form low retaining walls. The fences trap surface flow and sediment and eventually take root to establish riparian vegetation. This method is best used for protection from surface flow and is not intended by itself to address erosion resulting from channel flow. Slope toe protection may be required.

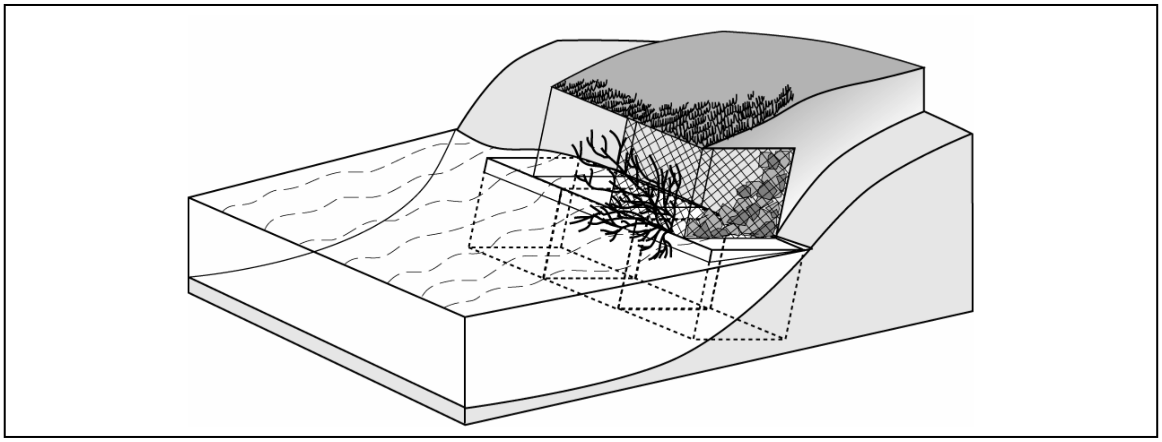
- **Log, Boulder and Root Wad Revetments**: Boulders, logs and/or root wads are attached together and anchored along the creek bank. Correct placement and orientation to flow is critical to prevent unwanted scour. Revetments trap sediment and provide cover for aquatic species, but may biodegrade before permanent vegetation is established. Heavy equipment is usually required to position the revetments. This technique may be used where access for heavy equipment is practical. Revetment placement and anchoring is a function of the specific channel structure and hydraulic conditions and as such should be determined in the project planning phase by the project engineer and geomorphologist. Use care to provide adequate anchoring when revetments are placed upstream of bridges or other areas of constricted flow.

Figure 1-11. Log, Boulder and Root Wad Revetments



- **Vegetated Gabions:** Rectangular wire mesh baskets filled with soil and small to medium sized rocks are stacked along the bank in a receding terrace and live cuttings of native woody species are inserted in the spaces between the baskets. Larger planting pockets can also be left in the upper tiers of the gabion terrace to accommodate the placement of rooted plant materials provided they have time to become well-established before high water events are expected. Supplemental irrigation will be required in these situations. Vegetated gabions are used for very steep bank stabilization.

Figure 1-12. Vegetated Gabions



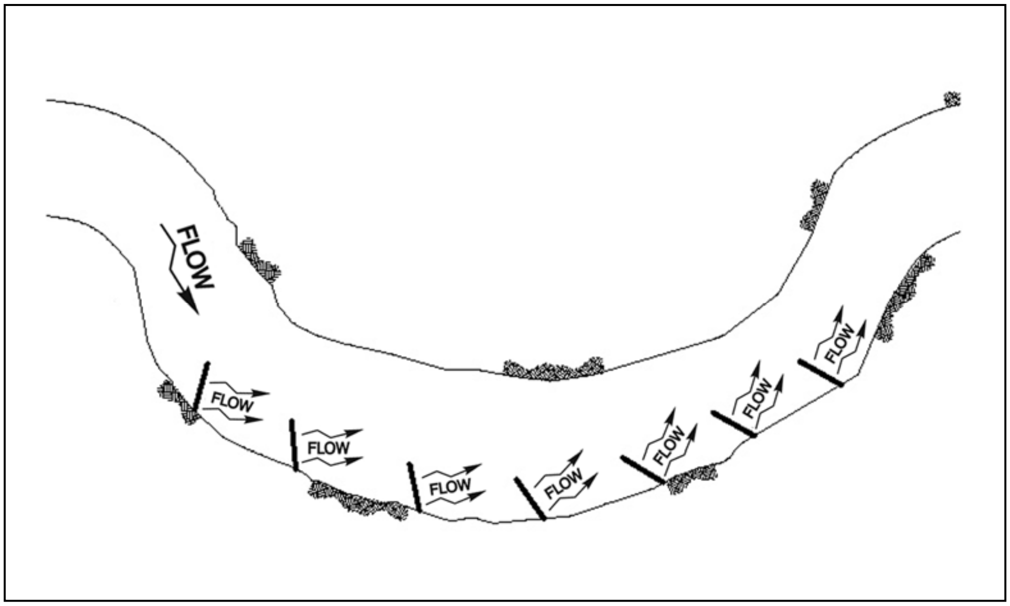
Flow Deflection

Flow deflection structures include those types of instream structures that tend to deflect erosive forces away from areas of bank instability. The general premise is to alter the course of the highest velocities by directing them inward towards the center of the channel. Benefits include increasing hydraulic variability and sediment sorting mechanisms. Along the downstream backside of the structures, a leave is created where sediments tend to accumulate, allowing emergent, herbaceous, and woody materials to regenerate, heal degraded stream banks, and grow outward towards the channel. This process results in increased sinuosity and an increase in riparian cover.

These types of structures are, however, less reliable than biotechnical methods applied directly to banks and are subject to the specific types of flood events and forces inherent in that particular system. In addition, great care must be taken to ensure that flanking along the backside of the structure does not occur during higher flood flows. The following in-stream flow deflection methods are appropriate for application in the Roseville Creek corridors.

- **Bendway Weir:** A bar of submerged rock is placed in the bend of the channel with one end anchored to the bank and the other end extending into the channel. The structure is usually angled from 0 to 30 degrees toward the upstream direction. The specific location, angle, and number of weirs are based on site conditions. The weir(s) should be high enough to intercept enough flow to reduce bank erosion on the outside bank of the bend but not so high as to impede flood conveyance. Bendway weirs alter secondary currents on the outside of a bend by redirecting high velocity flow and dissipating energy in the area of the bend.

Figure 1-13. Bendway Weir Placement



- **Log, Rock or J-Rock Vane:** A vane is a linear structure that extends from the stream bank approximately 1/3 of the bankfull width into the channel and is angled toward the upstream direction at 20 to 30 degrees. The downstream end is set at the bankfull elevation and the upstream end at the bottom of the channel. Vanes are used to redirect flow towards the center of the channel thereby reducing erosion of the bank. They are commonly used to address erosion at the toe of banks. Either rock or logs can be used to construct a vane. Both must be properly anchored and/or keyed to the bank and channel bottom to keep them in place. Proper design and installation is very important so that the features do not cause eddy scour of the bank on the upstream side or excessive pool scour on the downstream side. J-rock vanes are the same as regular rock banes except the end in the creek curves around in a "J" shape to enhance the formation of downstream scour pools.

Figure 1-14. Log Vane

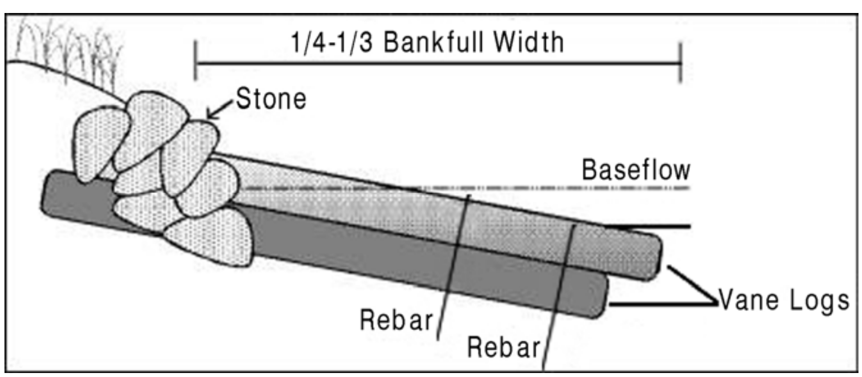
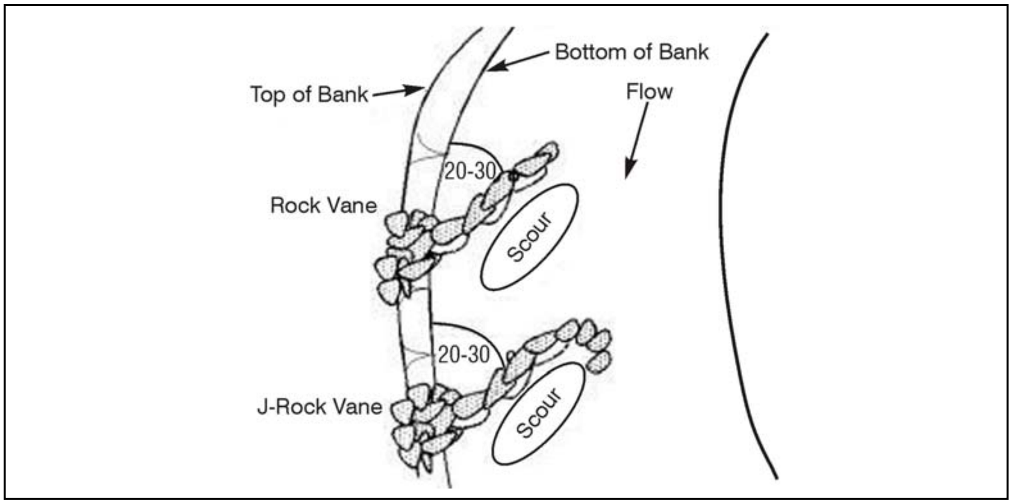


Figure 1-15. Rock and J-Rock Vane



Hardscape

Hardscape refers to the placement of rock (i.e. cobbles, large boulders, angular rock, and non-vegetated gabions) or concrete (i.e. articulated block, retaining walls, and deflection walls) into reaches where banks are steep, erosion is imminent, and velocities exceed 7 to 10 feet per second. Of all of the erosion/stabilization measures, hardscape is the most reliable and longest lasting form of protection. However, its negative impact on the biological value of the creek is severe. Placement of rock or concrete bank stabilization measures generally results in the loss of riparian habitat. Wherever possible, some provision should be made to include a vegetative element in the design of bank stabilization projects that rely on hardscape techniques. Some examples of such improvements are terracing retaining walls and leaving a planting pocket behind each level, or placing live stakes in the spaces between cobbles or riprap.

As a general rule, and in the interest of creek habitat preservation, hardscape should be used as a last resort and where other options are deemed infeasible. However, if a hardscape approach is required, boulder revetments and imbricated rip-rap may provide a marginally more naturalistic appearing solution than manufactured block, retaining walls, traditional rip-rap or non-vegetated gabions.

- ***Boulder Revetment:*** *A boulder revetment is constructed by placing a series of boulders along the toe of a creek bank or extending part of the distance up the bank. Single boulder revetments have one row of stone above a row of keyed in footer stones. If additional bank protection is needed a double layer boulder revetment can be used. Alternatively, a single row of very large boulders 3 feet to 4 feet tall can be used to create the revetment. In this application no footer stones are used and the large boulders are entrenched below the creek bottom to prevent scour and dislodgement.*

Figure 1-16. Single Boulder Revetment

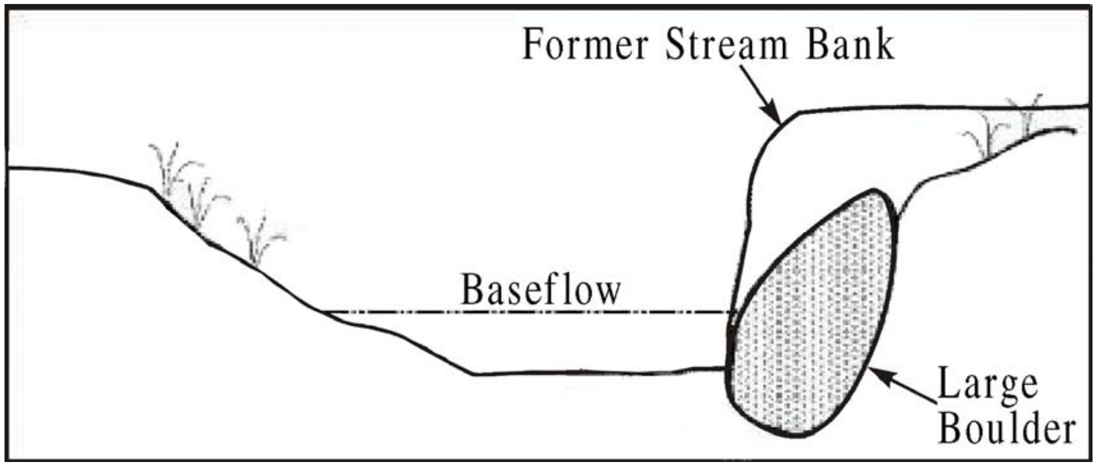
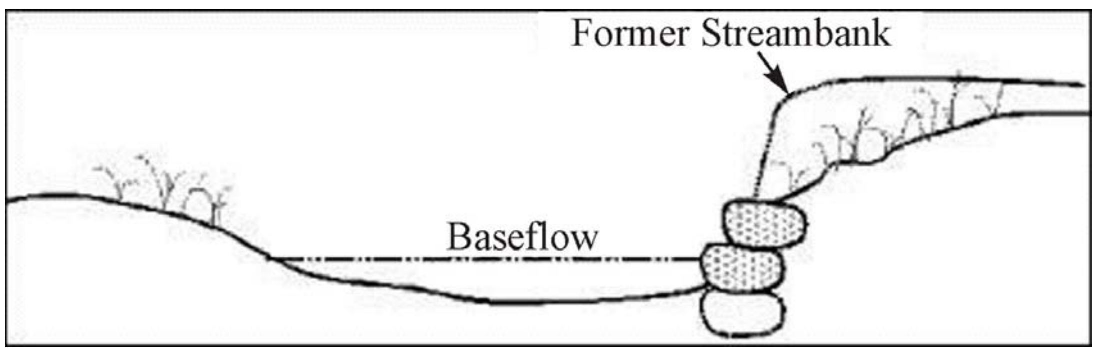
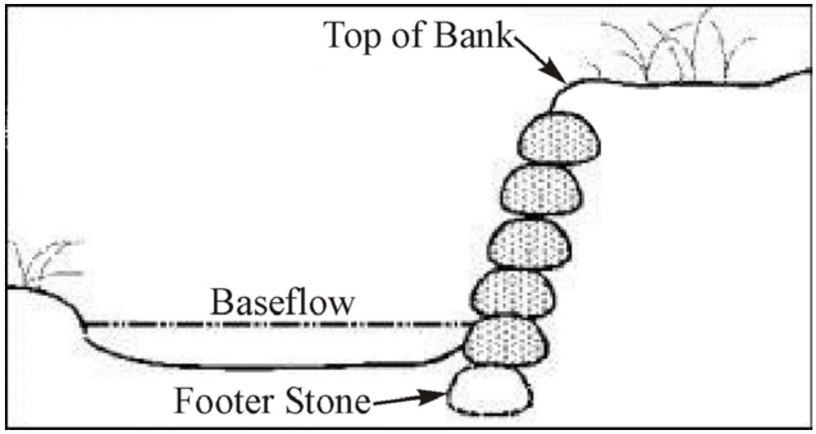


Figure 1-17. Double Boulder Revetment



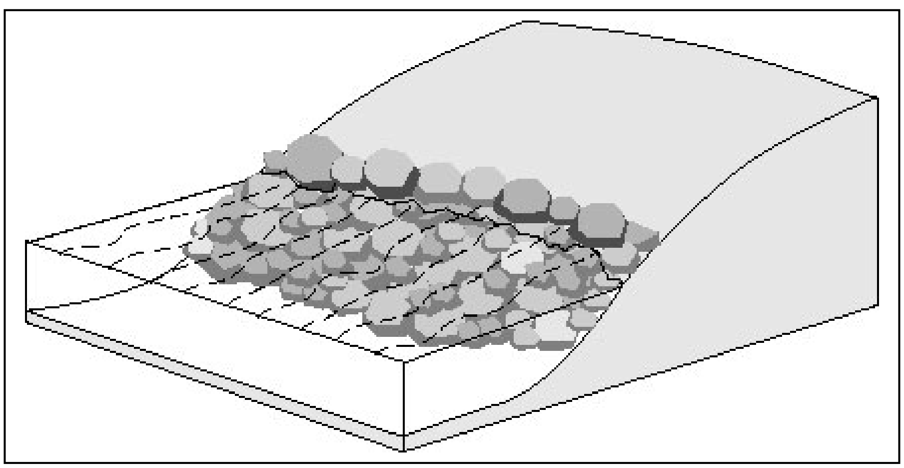
- **Imbricated Rip-rap:** This technique is similar to a boulder revetment but uses large two to three foot long flat or rectangular boulders staked up the entire face of the creek bank with a slight batter for stability. A layer of geotextile fabric is usually placed behind the stones to reduce erosion. This technique is one of the few stabilization options for nearly vertical banks where there is not adequate room to lay back the bank to a more stable angle.

Figure 1-18. Imbricated Rip-rap



- **Stone Toe Protection:** In some situations, a limited amount of hardscape may need to be situated at the toe of the slope to provide stabilization either by itself or in combination with other methods. In these situations, stream cobble or similarly sized quarried rock is placed at the toe of the stream bank and slightly below the water line to deflect flow and to potentially promote sediment deposition.

Figure 1-19: Stone Toe Protection



<u>Stabilization Materials</u>

Stabilization materials are often used to control bank erosion while revegetation is becoming established. The natural materials such as coir will biodegrade over time, but the synthetic materials will not. Some apparently natural materials (wood fibers) also use nylon mesh to hold the fibers in place and this mesh will not biodegrade. Synthetic materials are best suited to temporary applications where the intention is to eventually remove the product.

Many synthetic and natural materials, fabrics, and components are being developed, introduced, and tested for projects in association with erosion protection and bank stabilization. These types of measures provide a wide variety of physical and biological benefits and vary in reliability, effectiveness, and cost. Some of the most commonly used materials are:

- Geotechnical Soil Stabilizing Components and Networks,
- Synthetic Geotextiles,
- Synthetic Erosion Control Blankets,
- Synthetic Filter Fabrics,
- Natural Jute or Coir Fabrics,
- Natural Jute, Coir, or Straw Components, and
- Synthetic and Natural Fibers.

It is important to obtain the manufacturer's current specifications for use and installation instructions before selecting any of these products for a bank stabilization project since they are constantly being redesigned and improved.

1.4 Channel Realignment

1.4.13 Benefits

Channel realignment is used to intentionally direct the channel forming forces of the creek. Realignment efforts aim to establish a creek system that will accommodate the range of anticipated vertical and lateral channel movements in a manner that protects property, public safety and enhances habitat conditions. Channel realignment can be used specifically to create more sinuosity, address incision, prevent erosion, and to create a more well-defined low flow channel. More sinuosity increases aquatic habitat diversity and can increase channel capacity. Spreading out flows from deeply incised channels increases the diversity of riparian vegetation. A well defined low-flow channel decreases the water surface area thereby decreasing the amount of solar radiation transferred to the water, reducing the rate of increase in creek temperatures. The narrower channel will also allow vegetation to establish itself closer to the channel centerline or thalweg, providing increased shading that will aid in maintaining reduced temperatures.

1.4.14 Where Appropriate

Bank realignment should be considered where any of the following conditions exist:

- Banks are exposed and/or eroding
- Hardscape stabilization measures have been used to protect property and adequate access open space makes realignment feasible
- Low flow channel is absent or poorly defined

- Channel is deeply incised and riparian vegetation is losing hydrologic connection to creek

- Creek channel lacks sinuosity

- Channel sections lack topographic diversity (terracing)

1.4.15 General Practices

<u>Planning</u>

- Design realignment to minimize disruption of existing valuable riparian vegetation.

- Utilize existing topography and remnant channel features when feasible.

- Look for opportunities to provide a diversity of habitat types through the realignment of the channel, such as seasonal wetlands, side channels, etc.

- All channel realignment projects should include an evaluation of the potential for upstream and downstream hydraulic impacts and of the localized hydrologic conditions. The project must be consistent with the City's flood management requirements.

- The objective(s) for the realignment project need to be clearly defined and evaluated for overall consistency with the ecological objectives of the larger creek system.

- The channel realignment design should be evaluated for consistency with projected future flow conditions and sustainability of the resultant ecosystem.

- Schedule project activities to avoid disruption of fish migration or include provisions for bypass measures in project design.

- Include measures to prevent siltation of downstream reaches during construction.

- Identify other restoration strategies that need to be included with the realignment project such as bank stabilization, bank recontouring, in-stream structures, grade controls, and/or revegetation. Design all components as part of an integrated approach to restoration using a multi-disciplinary team with expertise in hydrology/hydraulics, geomorphology, civil engineering, revegetation, and habitat enhancement.

- Try to balance cut and fill requirements to minimize need for offsite disposal and/or importation of soil and rock.

- If soil and rock must be imported, use materials that have been collected from the local watershed or that are geologically comparable to local materials.

- Identify how any required flow diversion will be handled and the period of time the diversion will be required. Make sure to address hydraulic impacts of the flow diversion approach to prevent erosion and damage to the channel, and any potential impacts to aquatic species. The decision as to the type of flow diversion method(s) to be used should be made by the project engineer, aquatic biologist, and geomorphologist in consultation with the City's Public Works department.

Plan Review

- A plan of the proposed channel realignment project should be prepared and reviewed by the City before implementation. The plan should include the extent of the project, description of impacts to existing vegetation, timing, grading plan, cut and fill calculations, diversion strategies, the results of any hydraulic/hydrologic analyses, and specific erosion control measures to be implemented during the construction phase. Information as required by this Plan for any other restoration strategies (revegetation, bank stabilization, etc.) should also be included.

Installation

- Make sure that project area is secured from public access to prevent accidents and injury.

- Identify any vegetation adjacent to the project area that is to be protected and provide protective fencing around the critical root zone.

- Harvest any native plants that are to be replanted in the finished project and establish them in a suitable temporary location.

- Stockpile topsoil to be redistributed on finished grade.

- Where bank erosion presents an imminent threat to property and/or public safety, the use of temporary hardscape stabilization techniques may be required. A strategy should be developed for replacement of these techniques with a more ecologically appropriate technique when/if the imminent threat passes.

- Proper anchoring of stabilization materials is necessary to prevent dislodgement of materials that could cause flow obstructions, injuries to wildlife, hydraulic impacts, or downstream hazards. The project engineer and geomorphologist should identify anchoring methods.

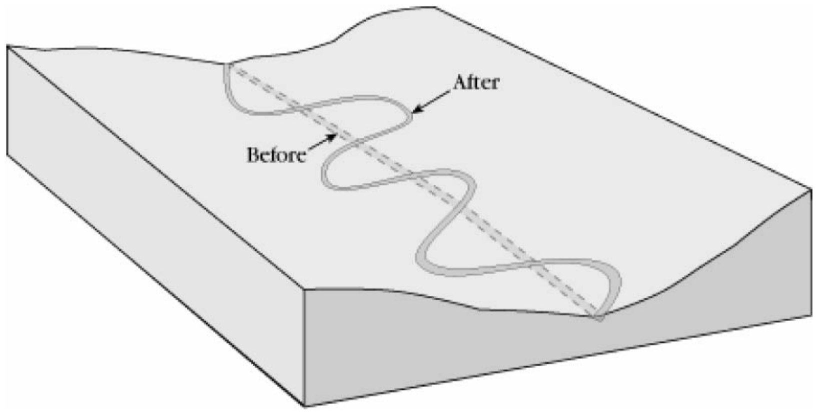
1.4.16 Techniques

Excavation & Grading

Channel realignment can be accomplished by physically grading the existing channel and adjacent floodplain to the desired topographic configuration. This technique can be highly disruptive of existing vegetation, require extensive measures to protect downstream areas from siltation, complicated to execute properly, and expensive. However, it also provides the ability to quickly and precisely implement major changes in the creek geometry on a large scale. This method should be used when in-stream structures or grade controls (discussed below) alone are not adequate to create the required magnitude of change in the desired timeframe. For example, projects that require a major modification to the profile of the channel or relocation of the thalweg may best be accomplished by excavation and grading

Excavation and grading may be used alone or in conjunction with in-stream structures and grade controls to define the topographic features of the channel, including the low-flow channel, thalweg, terraces, pools, and meanders. Excavated channel realignment projects require careful planning for heavy equipment access to minimize soil compaction and disturbance in areas that are not to be graded.

Figure 1-20. Channel Realignment



<u>Non-excavation</u>

A lesser degree of channel realignment can be accomplished by installing structures in the channel that influence sediment deposition, scouring, and flow velocity. These measures include in-stream structures and grade controls and are discussed in sections 1.5 and 1.6 below. These types of measures are less disruptive of existing vegetation and result in more modest and gradual changes to creek geometry. These measures should typically be used to address specific and discrete areas where the desired adjustment to the creek can be accommodated within the existing bankfull channel, and the overall alignment is to be retained.

1.5 In-stream Structures

1.5.17 Benefits

In-stream structures provide opportunities to improve hydraulic diversity and sediment management mechanisms, produce riffles or pools, develop different types of epifaunal substrate, redirect erosive flows, improve the low-flow channel, increase sinuosity, and (especially in the Dry Creek watershed) provide clean pockets of spawning gravels suitable for chinook salmon and steelhead. In-stream structures can also act as sediment traps and attenuate storm peak flows.

1.5.18 Where Appropriate

In-stream structures should be considered for implementation where any of the following conditions exist:

- Banks are exposed and/or eroding

- Low-flow channel lacks definition

- Base flow is overly shallow or shifting

- Thalweg lacks sinuosity

- Reach lacks diversity of flow/depth regimes (slow-deep, slow-shallow, fast-deep, fast-shallow)

- Occurrence of riffles is infrequent with distance between riffles divided by reach width greater than 7.

- Cobble and gravel particles forming riffles are more than 20% embedded.

- Pools are absent, sparse or shallow. Less than 30% of pool bottom is obscured due to depth and/or pools are less than 3 feet deep.

- Fish cover is sparse and/or fewer than 5 types of cover are present.

- Heavy sediment deposits are filling pools and blanketing substrate.

- Channel has down cut to bedrock and/or substrate shows little diversity.

1.5.19 General Practices

<u>Planning</u>

- Design of in-stream structures requires consideration of the full range of potential hydraulic and hydrologic impacts at the project site, upstream and downstream.

- Consider the type of structure(s) to use to best meet the overall ecosystem benefit for the creek system. Some structures may improve conditions for certain species while adversely impacting others.

- Be sure that the project plan addresses the potential for in-stream structures to deflect flows against an unstable bank or to increase undesirable scour.

- The selection and placement of in-stream techniques should be made by a team with expertise in geomorphology, hydraulics, engineering, and aquatic ecosystem function.

- Multiple in-stream techniques may be needed in concert with other types of strategies (such as bank contouring, revegetation, and/or bank stabilization) to accomplish the full range of restoration objectives.

- Schedule project activities to avoid disruption of fish migration or include provisions for bypass measures in project design.

- Include measures to prevent siltation of downstream reaches during construction.

- When feasible, use naturally occurring materials found on or near the project site to construct the in-stream features.

- If soil, root wads, logs, rock, etc. must be imported, use materials that have been collected from the local watershed or that are comparable to local materials.

- Identify how any required flow diversion will be handled and the period of time the diversion will be required. Make sure to address hydraulic impacts of the flow diversion approach to prevent erosion and damage to the channel, and any potential impacts to aquatic species. The decision as to the type of flow diversion method(s) to be used should be made by the project engineer, aquatic biologist, and geomorphologist in consultation with the City's Public Works department.

Plan Review

- A plan of the proposed in-stream structure(s) should be prepared and reviewed by the City before implementation. The plan should include the extent of the project, description of impacts to existing vegetation, timing, diversion strategies, plan and section details for the structures, anchoring specifications, the results of any hydraulic/hydrologic analyses, and specific erosion control measures to be implemented during the construction phase.

Installation

- Make sure that project area is secured from public access to prevent accidents and injury.

- Harvest any native aquatic plants that are to be replanted in the finished project and establish them in a suitable temporary location.

- Proper anchoring of materials is necessary to prevent dislodgement of materials that could cause flow obstructions, injuries to wildlife, hydraulic impacts, or downstream hazards. The project engineer and geomorphologist should identify anchoring methods.

1.5.20 Techniques

Cut-off Sill

A cut-off sill is a low row of rock that extends from the bank toe into the creek channel in an upstream direction at approximately 20 - 30 degrees from the bank. This type of structure is very similar to a rock vane (see Figure 1-15) but its profile is lower and is usually well below the bankfull water surface elevation. Cut-off sills are used to narrow a channel and better define the low-flow channel by encouraging deposition and bar formation along the channel's edge. This technique may also be used to stabilize existing bars by installing the sills directly in the bar and with the top of the structure extending only slightly above the top of the bar.

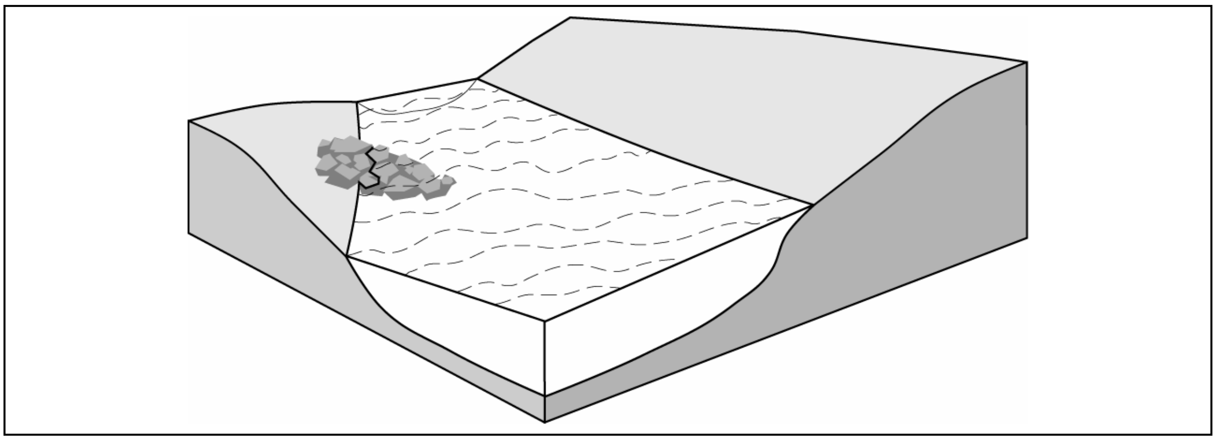
Linear Deflector

A linear deflector consists of a line of boulders placed in the creek channel parallel to the bank and at some distance away from the bank for the purpose of narrowing, deepening and better defining the low-flow channel. The tops of the boulders are usually well below the bankfull water surface elevation. The area between the deflector and the bank may include cut off sills and be left to fill in with sediment naturally, or it may be backfilled at the time of construction. Since this technique concentrates flows in a smaller area care needs be taken to insure that the opposite bank is stable or has some form of stabilization in place.

Boulder Wing Deflector (Single or Double)

A triangular structure consisting of a rock filled log frame or entirely of rock is placed with the wide end at the bank and the pointed end extending into the channel (single wing). A double wing deflector consists of the same structure placed on bath sides of the channel. Wing deflectors are used to narrow and/or deepen the base flow channel and to create sinuosity. Double wing structures can also enhance riffle habitat above and between the structures and scour pools downstream. The wide end of the wing is placed at the higher of the bankfull elevation or the top of bank. The pointed end grades down to the channel bottom and about 1/3 of the way across the channel. Single wing deflectors have the potential to cause erosion on the opposite bank so careful design and analysis of hydraulic impacts is important.

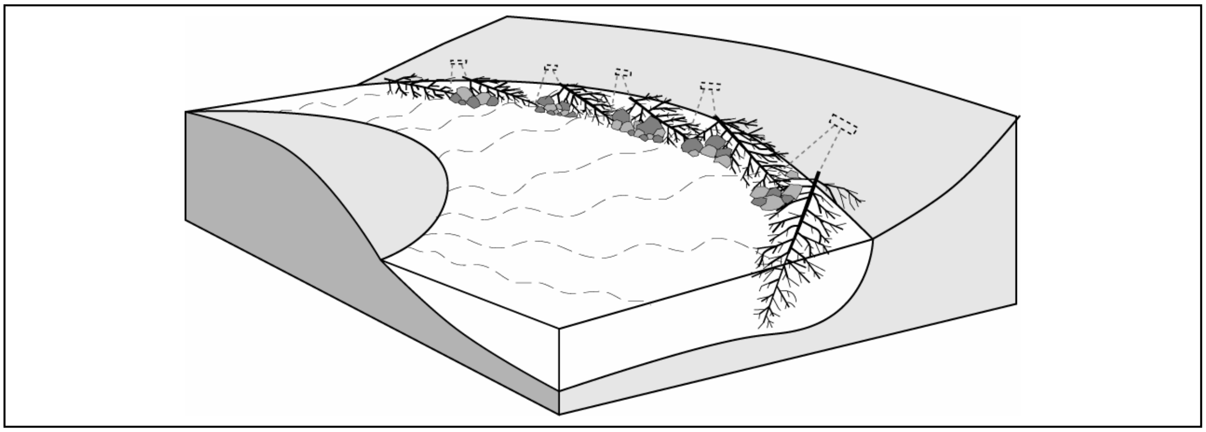
Figure 1-21. Single Wing Deflector



Large Woody Debris (LWD)

If LWD falls within the stream channel, it should be realigned parallel to the flow of water and left in place, unless it increases the risk of flood damage to neighboring or upstream properties. If the LWD poses a threat to downstream structures, it should be anchored to the bank sufficiently to prevent it from moving downstream during floods. The amount of LWD left resident in a channel cannot be allowed to compromise the flood conveyance requirements for that reach.

Figure 1-22. Large Woody Debris



Deflection Structures

Several in-stream techniques used for bank stabilization are also suited for making changes to the channel itself. See the discussion in section 1.3.12above on **bendway weirs** and **log, rock and j-rock vanes**.

1.6 Grade Control

1.6.21 Benefits

The purpose of grade controls is to maintain a desired streambed elevation by either preventing incision or by encouraging deposition, and to introduce hydraulic diversity in the channel. Designing the low-flow and bankfull channels to have some turbulent waters such as small waterfalls or cascading riffles will help to oxygenate the water and increase hydraulic diversity within the creek system. Well mixed waters have fewer problems with stagnation and anoxic effects, and are more efficient at removing nutrients and decreasing the biological oxygen demand (BOD). One very important benefit of the grade control structure is its ability to maintain a riffle in a designated space within an increasing flow regime.

In areas where channel incision is occurring or has occurred, grade control structures may be constructed to ensure that vertical channel movement ceases. In many cases where sediment transport characteristics are sufficient, the channel thalweg can be trained and the elevation of the channel bottom can increase, thereby reducing the effects of historic channel incision and reconnecting the hydrologic connection to the riparian vegetation.

1.6.22 Where Appropriate

Grade controls should be implemented where any of the following conditions exist:

- Reach lacks diversity of flow/depth regimes (slow-deep, slow-shallow, fast-deep, fast-shallow)
- Cobble and gravel particles forming riffles are more than 20% embedded.

- Heavy sediment deposits are filling pools and blanketing substrate.

- Pools are absent, sparse or shallow. Less than 30% of pool bottom is obscured due to depth and/or pools are less than 3 feet deep.

- Extreme vertical changes in existing creek bottom are causing excessive scour and or erosion

- Extreme vertical changes in existing creek bottom are creating migration barriers for fish

- Discharge from a culvert or outfall is degrading the channel

- A nick point has formed and is migrating headward

1.6.23 General Practices

Planning

- Design of grade control structures requires consideration of the full range of potential hydraulic and hydrologic impacts at the project site, upstream and downstream.

- Consider the type of structure(s) to use to best meet the overall ecosystem benefit for the creek system. Some structures may improve conditions for certain species while adversely impacting others.

- Be sure that the project plan addresses the potential for grade control structures to increase undesirable scour.

- The selection and placement of grade control techniques should be made by a team with expertise in geomorphology, hydraulics, engineering, and aquatic ecosystem function since these decisions must respond to individual site constraints such as flow level, velocity, channel width, and sinuosity.

- Multiple grade control techniques may be needed in concert with other types of strategies (such as bank contouring, revegetation, and/or bank stabilization) to accomplish the full range of restoration objectives.

- Schedule project activities to avoid disruption of fish migration or include provisions for bypass measures in project design.

- Include measures to prevent siltation of downstream reaches during construction.

- When feasible, use naturally occurring materials found on or near the project site to construct the in-stream features.

- If soil, logs, rock, etc. must be imported, use materials that have been collected from the local watershed or that are comparable to local materials.

- Identify how any required flow diversion will be handled and the period of time the diversion will be required. Make sure to address hydraulic impacts of the flow diversion approach to prevent erosion and damage to the channel, and any potential impacts to aquatic species. The decision as to the type of flow diversion method(s) to be used should be made by the project engineer, aquatic biologist, and geomorphologist in consultation with the City's Public Works department.

Installation

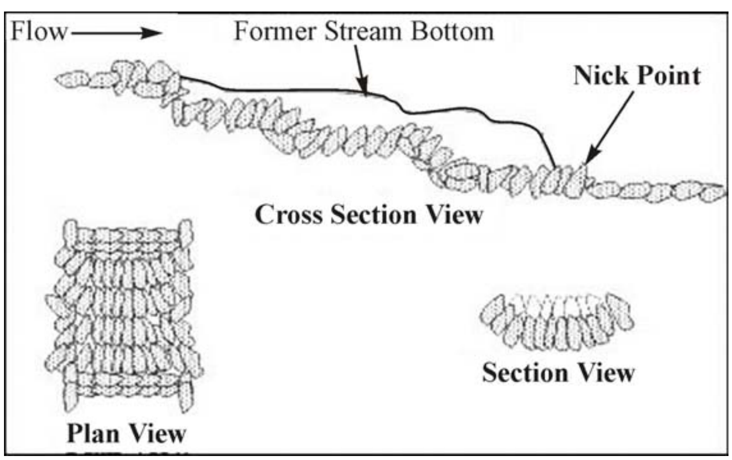
- Make sure that project area is secured from public access to prevent accidents and injury.
- Harvest any native aquatic plants that are to be replanted in the finished project and establish them in a suitable temporary location.
- Proper anchoring of materials is necessary to prevent dislodgement of materials that could cause flow obstructions, injuries to wildlife, hydraulic impacts, or downstream hazards. The project engineer and geomorphologist should identify anchoring methods.

1.6.24 Techniques

Step Pools

Step pools are used to dissipate energy in steep sections of the creek to control erosion and scouring. They are good techniques to use to stop headward migrating of a nick or to address channel degradation below an outfall or culvert. The structure consists of placing large rock in alternating short, steep sections with longer low or reverse grade sections. The rock used must be large enough to be immobile, and the drops should be low enough to allow migration of aquatic species. Some step pools include sections of open creek bottom (no rock) between the rock sections to allow development of scour pools or to provide glides after the riffles. The specific dimensions of the steps and size of rock to be used are determined by the conditions of the specific reach, such as existing grade, flow velocity, extent scour occurring, etc.

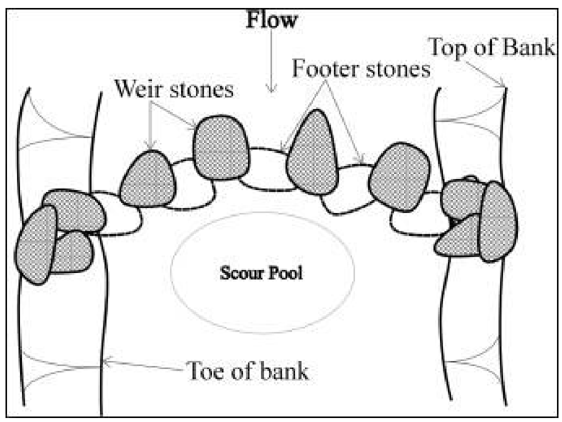
Figure 1-23. Step Pools



Rock Vortex Weirs

A rock vortex weir consists of a curved row of stones positioned across the creek channel and pointing upstream with the legs of the weir oriented 15 to 30 degrees relative to the stream bank. The weir structure includes a base layer of large 2 – 3 foot boulders placed as a footing in a trench excavated in the creek bottom. Large stones are then placed in the trench behind and against the footing stones to the desired elevation. The weir stones do not touch each other but are separated by about 1/3 to ½ the diameter of the stones. The legs of the weir extend to just above the bankfull elevation and the weir stones in the channel are kept to about 10 to 15% of the bankfull height. During baseflows, the creek passes through the openings between the stones and creates diversity of flow velocity and depths. At high flows, water passes over the stones and creates a scour pool on the downstream side of the weir while still allowing bed load sediments to pass through. Rock vortex weirs are best used to prevent grade changes than to stop active changes such as migrating nick points.

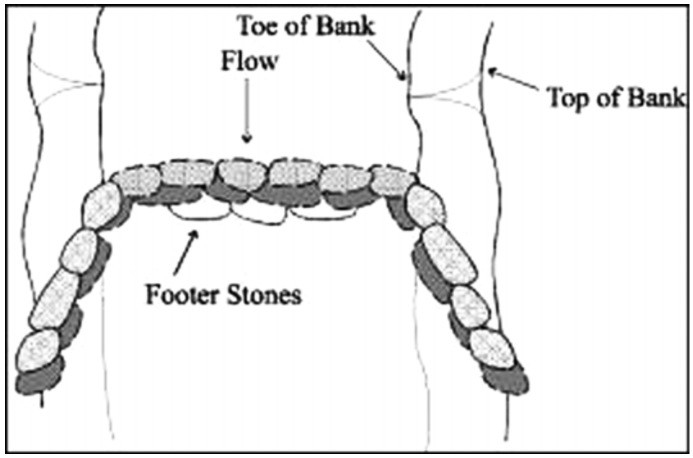
Figure 1-24. Rock Vortex Weir



Rock Cross Vanes

A rock cross vane is similar to a rock vortex weir but the stones extend very little if at all above the creek invert. This technique is used to narrow the base flow channel and to provide grade control. The vane is constructed perpendicular to the flow with legs extending downstream and rising gradually to the bankfull elevation. The width of the sill portion of the structure is determined based on the desired width of the channel. Depending on how much channel width reduction is created, scour pools may form below the structure. The number of courses and size of stone is determined based on the size of the creek, potential for scouring, and substrate characteristics.

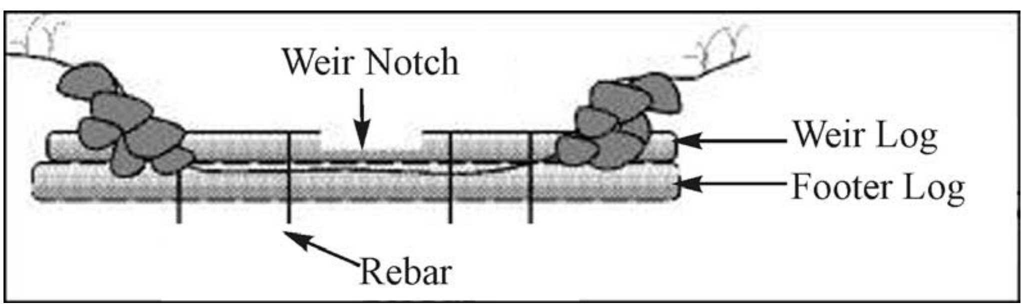
Figure 1-25. Rock Cross Vane



Log and V-Log Drops

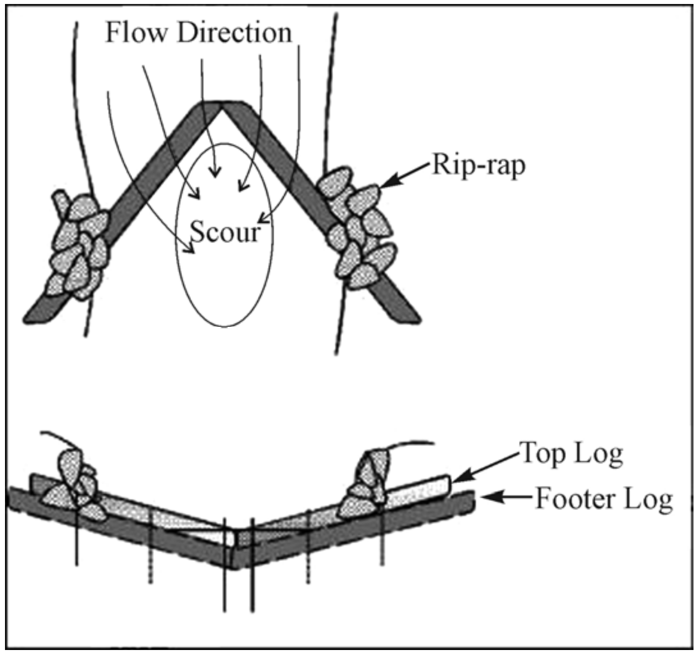
Log drops are used to form pools and to provide grade control in a manner that imitates the influence of large wood debris (LWD). Two large (16" diameter or greater) logs are placed one on top of the other, with the bottom log situated in a trench cut across the creek channel. The top of the upper log should be just below the base flow level of the creek. A weir notch is cut in the upper log to concentrate flow to scour out a pool below the structure. The use of log drops should be very carefully assessed because they can result in upstream sedimentation and a reduction of the channel cross sectional area. If flows exceed the capacity of the notch, their may be potential for bank erosion as the flow spreads out over the entire length of the structure. If this type of structure is only used for grade control, the upper log should not rise above the invert of the creek.

Figure 1-26. Log Drop



V-log drops are a variation of the log drop in which the logs are oriented in a V pointing upstream. The low point is at the apex and the legs rise into the bank. This approach does not create a fish barrier or result in upstream sedimentation. It also more effectively concentrates flows towards the center of the channel, thus reducing reduces the potential for bank erosion and channel widening, and enhancing scour pool formation. Both variations of the log drop approach require anchoring and bank stabilization.

Figure 1-27. V-Log Drop



1.7 Removal of Fish Barriers

1.7.25 Benefits

Fish barriers are obstacles that prevent or delay fish from moving either upstream or downstream. They may be in the form of physical objects located in the channel, the result of inadequate water levels, or a combination of both. The removal of fish barriers is more of a concern in the Dry Creek watershed than in the Pleasant Grove watershed because the Dry Creek system provides more favorable salmonid habitat.

Removing barriers improves the potential for the migrating adults to access the desirable spawning and rearing reaches, and facilitates the exodus of the juveniles when they are ready to leave the freshwater system. Consequently, loss of access to habitat reduces overall fisheries productivity. Barriers can also cause fish to congregate in areas below or above the barrier leaving them vulnerable to predators and can create unsuitable living and breeding conditions that can increase disease incidence.

1.7.26 Where Appropriate

Fish barrier removal should be considered where any of the following conditions exist:

- Channel obstructions/flow levels prevent migration of adult salmonids to potential spawning/rearing habitat.

- Channel obstructions/flow levels prevent emigration of juvenile salmonids out of the system.

- In situations where implementation of the passage improvement will not adversely impact other aquatic species and creek function.

1.7.27 General Practices

The City is aware of several fish passage issues in the Dry Creek watershed and has either corrected the problems or is in the process of developing plans to do so (Appendix E.)

Planning

- Since spawning and emigration occur at different times, barriers need to be identified relative to the flow levels associated with both life stages. It is important to remember there is the potential for adverse impacts to other species by removing barriers that may provide desirable cover or hydraulic conditions for these other species.

- Fish barriers are typically eliminated by construction of some type of passage improvement(s) (see Techniques below), actual physical removal of the barrier, or a combination of these two methods. Consider the approach that best meets the overall ecosystem benefit for the creek system. Some structures may improve conditions for certain species while adversely impacting others.

- Through migration/emigration surveys and field assessment identify where and when barriers exist and where the spawning/rearing reaches are located. Prioritize improvements to maximize habitat benefits. For example, upstream improvements should typically proceed after downstream improvements.

- Since channel conditions can change over time, periodically resurvey the channel to detect new barriers.

- Make sure that improvement design will function as intended with the flows anticipated at the critical times of the year.

- For culverts or other type of flow conducting improvements, make sure that adequate capacity is provided to account for future embeddedness.

- Consider the full range of potential hydraulic and hydrologic impacts at the project site, upstream and downstream, including the ability of the improvement to successfully pass storm flows, sediment and woody debris.

- The design and location of fish passage improvements should be made by a team with expertise in aquatic ecology, fisheries, geomorphology, hydraulics, and engineering since the improvements must respond to individual site constraints such as flow profile at various flow ranges, velocity, channel width, and substrate conditions as well as particular habitat requirements for the anticipated species.

- Schedule project activities to avoid disruption of fish migration or include provisions for bypass measures in project design.

- Include measures to prevent siltation of downstream reaches during construction.

- When feasible, use naturally occurring materials found on or near the project site to construct the in-stream features. Use materials that provide the most naturalistic looking improvement while still accomplishing the design intent of the project.

- If soil, logs, rock, etc. must be imported, use materials that have been collected from the local watershed or that are comparable to local materials.

- Identify how any required flow diversion will be handled and the period of time the diversion will be required. Make sure to address hydraulic impacts of the flow diversion approach to prevent erosion and damage to the channel, and any potential impacts to aquatic species. The decision as to the type of flow diversion method(s) to be used should be made by the project engineer, aquatic biologist, and geomorphologist in consultation with the City's Public Works department.

Installation

- Make sure that project area is secured from public access to prevent accidents and injury.

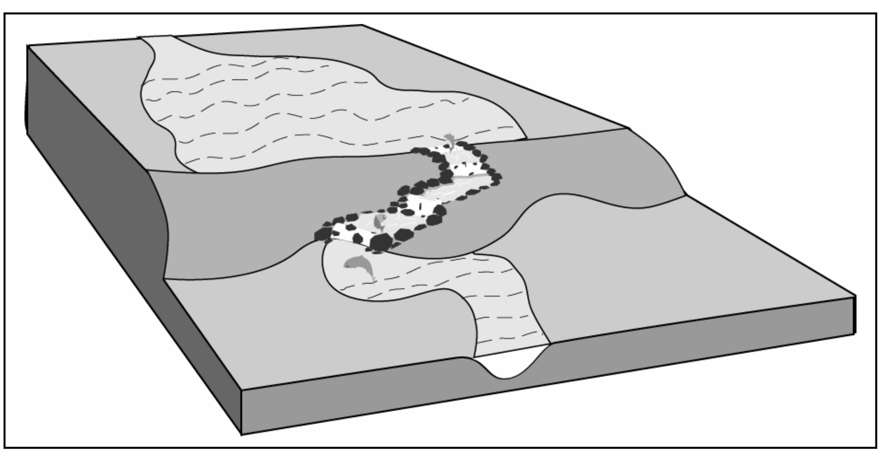
- Harvest any native aquatic plants that are to be replanted in the finished project and establish them in a suitable temporary location.

- Proper anchoring of materials is necessary to prevent dislodgement of materials that could cause flow obstructions, injuries to wildlife, hydraulic impacts, or downstream hazards. The project engineer and geomorphologist should identify anchoring methods.

1.7.28 Techniques

Fish passage improvement techniques are designed to eliminate barriers by providing a route with the flow, slope, water quality, and channel structure characteristics that are compatible with the target species needs. For migrating adults, the improvement is typically needed to provide a gradual upstream change in elevation and may be accomplished using the grade control techniques, such as step pools, described in the prior section.

Figure 1-28. Fish Passage Step Pools



Fish Ladders

A fish ladder (also known as a fish way or fish pass) is an inclined structure consisting of a series of weirs or baffles placed in the creek channel that facilitates upstream migration of fish by correcting conditions that might otherwise function as barriers, such as overly steep gradient or lack of flow. There are many different types of fish ladders ranging from simple step pools to complex manufactured concrete structures. Fish ladders may be recommended when blocking structures are as low as 1 to 2 feet in height. Critical components to determine when a ladder is necessary include flows, energy dissipation, resting areas, drop between pools, attraction velocities, entrance eddies, pool capacity, the fish species that need to pass, and potential impacts on other aquatic species.

Bypass Channels

Bypass channels are constructed to provide a passage route by which migrating fish can circumvent some type of barrier in the main channel. The placement and design of the bypass channel requires all of the same considerations as any channel realignment project (discussed above) as well as an in depth understanding of the habitat and passage requirements of the specie(s) expected to use the channel. The bypass channel may be designed to operate only at certain times of the year with access controlled by weirs, gates, or other methods. Flow and egress are key considerations in the design of bypass channels to avoid stranding.

Screens

Fish screens are used to protect fish from hazards such as pump intakes and in some cases to prevent fish from moving into undesirable habitat via false attraction. There are many types of fish screens, and their effective use requires consideration of various factors such as water velocity, angle of approach, size of openings, anticipated species, time of operation, impacts on other aquatic species, maintenance costs, and possible flood management concerns since screens can trap debris and become blocked.

Culverts

When a creek passes beneath a road it is preferable to create a bridge crossing that is wide enough to accommodate the natural channel profile. However, in some cases this is not feasible and culverts are used to convey the flow from one side of the road to the other. Culverts can be serious fish passage barriers because of their gradient, limited volume, velocity of flow within the culvert, and hydrologic conditions at the upstream and downstream ends. In particular, it is common for the invert elevation of the downstream end of the culvert to become higher than the water surface elevation as the channel bottom drops over time from scour associated with the culvert discharge.

If culverts are the only solution for passing flows beneath a road, the project should be carefully designed to:

- maximize the cross sectional area of the opening at the water line,
- provide adequate flood conveyance capacity,
- limit scour associated with concentrating the flow,
- have adequate energy dissipating measures at the outfall,

- make sure the invert elevation is set low enough that fish can still enter the culvert even when flows are low,
- set the culvert at the correct gradient for the capabilities of the expected species,
- and maintain a channel profile as close to the natural condition as possible.

Box and arch culverts are generally better choices than traditional round culverts because they provide a wider cross sectional area. Open bottom culverts are preferred over closed bottom culverts because they allow the natural substrate, some in-channel habitat, and the natural gradient of the channel to remain in place. Where closed bottom culverts are used, non-angular boulders may be placed in the culvert to create some low-velocity micro-habitats and to help capture some stream bedload in the culvert. Culverts must be adequately sized to accept these types of components while still passing flood flows. Culvert maintenance must be performed on a regular basis to remove debris that may be impeding passage.

1.8 Beaver Management

1.8.29 Benefits

Beaver activity has the potential to make significant changes to ecosystem conditions in the creek corridors in both the Dry Creek and Pleasant Grove watersheds. With virtually no natural predators remaining, control of beaver populations presents a significant challenge. The goal of beaver management is to establish populations at an optimal level that balances the benefits of their presence with the associated adverse impacts. Beaver activity can be a positive force in the creek ecosystem by increasing aquatic habitat diversity and trapping sediment in their dams. However, an overabundance of beaver can lead to destruction of riparian vegetation, fish passage barriers, erosion, and flood control issues.

1.8.30 Beaver Management Policy

The City's Beaver Management Policy addresses criteria for determining if a management action is warranted, a progressive approach to management, and a population management protocol. The text of this policy is included as Appendix F to this Plan.

It is envisioned that this policy will be accompanied by a comprehensive Beaver Management Plan that addresses public education and outreach, the carrying capacity of the streams for beaver, remediation steps to prevent significant beaver impacts on local waterways, and monitoring beaver dam location and populations. Approval of this plan could serve as the basis for the programmatic approach outlined in Section 8.3.2 to facilitate beaver management in a balanced manner that would maintain the health of both the beaver population and the riparian habitat.

1.9 Invasive Plant Management

1.9.31 Benefits

Management of invasive plant species will help to increase the vigor and diversity of native plant species in the creek corridors by limiting competition for light and nutrients. As the native plant community becomes more robust, its value as habitat for native species of birds and wildlife will also increase. Flood control is another important reason to manage invasive plant populations. Many of the exotic species that proliferate in the creek corridors, such as giant reed (*Arundo donax*), red sesbania (*Sesbania punicea*), and water hyacinth (*Eichhornia cassipes*), produce significant quantities of biomass that reduce channel capacity and conveyance. As the biomass decomposes, there is an increased amount of organic material in the creek sediment which can substantially damage fish spawning and water fowl habitats.

1.9.32 Where Appropriate

- Invasive plant species management should be implemented anywhere populations of invasive non-natives are beginning to or have already become established in the creek corridor.
- Since these species are characterized by rapid colonization, it is most effective to begin management as soon as the species is detected and to provide for follow-up maintenance to prevent or at least control future establishment.
- Invasive non-natives may occur throughout the entire corridor, from the highest transitional upland terraces to within the creek itself.
- Consider including removal of invasive non-native plants into all restoration, revegetation, and maintenance activities.

1.9.33 General Practices

<u>Planning</u>

- Prior to beginning an invasives removal project, conduct an inventory to determine the extent, condition, and age of the population.
- Assess the potential area that will require revegetation once the non-native species are removed, and include a revegetation strategy as part of the project.
- Try to identify the local source for the species and establish a project boundary that is large enough to include individuals that could provide seed for future re-establishment. For aquatic species this may not be practical since they may spread rapidly floating great distances downstream.
- Identify any adverse impacts the removal project may have on wildlife or aquatic species and develop mitigation measures.
- Establish targets for post-project conditions such as percent removal, degree of control, or consistency with some visual standard.

- Based on the target species for removal, identify which removal methods will be used.

- Be sure staff or volunteers who will be participating in the removal effort are properly trained on plant identification and the proper way to implement the selected methods.

- Schedule the project so that the control methods selected will be coordinated with the species natural growth cycles for added efficiency. For example, If the species spreads by seed, conduct the project before seed is set.

Implementation

- Dispose of cut or harvested invasives outside of the creek corridor in a manner that assures the decomposition of the biomass and destruction of any viable seed.

- If a sizeable amount of invasive material is removed, make sure that native revegetation, erosion control, and slope stabilization measures are implemented immediately.

- Implement any measures that may be required to mitigate for temporary habitat loss while the native species are becoming established.

- Perform periodic monitoring to catch any germination or root sprouting of individual plants that may not have been successfully treated in the initial removal project.

1.9.34 Techniques

Many of the invasive species found in the City's creek corridors are described in Appendix C with an indicator of where they commonly grow, their nuisance factors, and preferred management techniques. In general, management requires the use of one or more of the following methods.

Manual Removal

Manual removal is used when heavy equipment would be impractical or cause damage to the creek channel. Manual removal provides a high degree of precision and selectivity, and is a good choice for relatively small areas or where isolated individual non-native plants are growing among other native species that are to be preserved. In some cases, manual removal is necessary to make sure that all portions of the plant structure are removed, including roots, seed pods, or vegetative shoots. Manual removal is also a good technique for volunteers since they can usually be easily trained to use the requisite tools.

Mechanical Removal

Mechanical removal employs the use of heavy equipment. This may be the only practical strategy if the infestation is very large or involves especially deep-rooted, heavy plants. Since mechanical methods are not very precise, it may be necessary to follow-up with other techniques to make sure that all of the invasive biomass was removed.

Erosion control, protection of desirable plants, and access routes must be carefully planned if heavy equipment if to be used.

Herbicide

Herbicides are less desirable for non-natives species management than manual or mechanical methods because of their potential for adverse environmental and water quality impacts if they are not used properly. However, for some species, this is the only effective means of control. If herbicides must be used, it is critical that the correct formulation be chosen that will accomplish the intended result with the least impact on other species. When available, selective herbicides that target a particular plant are preferred over non-selective products that will kill everything. Any removal strategy that includes the use of herbicides must be carefully planned with the assistance of a licensed herbicide professional to make sure that the minimal amount of the correct type of chemical is applied, at the optimal time, according to the label instructions to protect waterways and wildlife.

Cut and Paint

The cut-and-paint technique is a combination of manual and herbicide controls. When plants are putting out new shoots or actively growing, the branches are cut off near the ground and the cut surfaces painted with a system herbicide. The herbicide is translocated trough the plant tissue and the plant will eventually die. This method can be effective for some woody species, such as red sesbania, and provides a great deal of control over where the herbicide goes. Other species are so hardy that several applications may be required over successive years to achieve control.

Cutting Shoots and Root Removal

Cutting shoots and root removal is an environmentally safe way to remove woody non-natives but requires a great deal of effort over a period of years to see results. Cutting off shoots and removing as much root as possible substantially stresses the non-native plant. If this regime is kept up faithfully throughout successive growing seasons, the plant will eventually die. However, this technique may not be practical for large areas or if the human resources required to implement it are not available.

1.10 Runoff Controls

1.10.35 Benefits

Runoff controls are used to intercept and/or slow down surface flow coming from outside of the creek corridor before it enters the channel. These flows may originate from storms or from non-storm sources such as irrigation, car washing, hosing off driveways, etc. While these latter sources do not have much of an impact on flood conveyance, their cumulative impacts can degrade water quality. In the Pleasant Grove system, it is likely that these flows are also contributing to increased channel widening and the associated erosion and loss of mature oak trees. Controlling storm and non-storm runoff into the creek corridor will help to reduce erosion of banks, the associated sediment loading and loss of vegetation, and the amount of pollutants that enter the creek.

1.10.36 Where Appropriate

Runoff controls should be implemented where any of the following conditions exist:

- Sheet flow from adjacent areas is entering the creek channel

- Point discharge, such as from storm drain outfalls, is entering the creek channel, or the creek corridor

1.10.37 General Practices

Planning

- Work with the City of Roseville's Environmental Utilities Department to identify the source of the runoff and characterize its volume, quality, and frequency.

- Work with the City of Roseville's Environmental Utilities Department Determine if the discharge is regulated by the City's SMP Ordinance and can be reduced or eliminated.

- Based on the characterization of the runoff, identify the objectives for the control. Is the control intended to simply reduce or to completely eliminate the discharge? Does it need to slow down velocity and/or improve water quality? In what situations or time of year is the control needed?

- Identify the technique(s) that will best meet the control objectives.

- If a grassy swale, pre-treatment wetland, or settling basin is desired, evaluate how much physical area is available in the floodplain to determine if the approach is feasible.

- Identify any temporary or permanent impacts the control may have on flood conveyance, channel hydrology, or habitat and design appropriate mitigation measures.

- If a runoff control structure is to be built in the floodplain, design and locate it to minimize disruption of existing valuable riparian vegetation.

- Utilize existing topography and remnant channel features when feasible.

- Look for opportunities to provide a diversity of habitat types through construction of the control feature, such as seasonal wetlands, side channels, etc.

- All runoff control projects that include changes within the floodplain should include an evaluation of the potential for upstream and downstream hydraulic impacts and of the localized hydrologic conditions. The project must be consistent with the City's flood management requirements.

- If the runoff control will include instream work, schedule project activities to avoid disruption of fish migration or include provisions for bypass measures in project design.

- Include measures to prevent siltation of downstream reaches during construction.

- Identify how any required flow diversion will be handled and the period of time the diversion will be required. Make sure to address hydraulic impacts of the flow diversion approach to prevent erosion and damage to the channel, and any potential impacts to aquatic species. The decision as to the type of flow diversion method(s) to be used should be made by the project engineer, aquatic biologist, and geomorphologist in consultation with the City's Public Works department.

Plan Review

- For runoff control projects that involve construction within the floodplain, a plan of the proposed project should be prepared and reviewed by the City before implementation. The plan should include the extent of the project, description of impacts to existing vegetation, timing, grading plan, cut and fill calculations, diversion strategies, the results of any hydraulic/hydrologic analyses, and specific erosion control measures to be implemented during the construction phase.

Implementation

- For runoff controls involving revegetation, incorporate the Standard Practices outlined above in section 1.1 Revegetation.

- Make sure that project area is secured from public access to prevent accidents and injury.

- Identify any vegetation adjacent to the project area that is to be protected and provide protective fencing around the critical root zone.

- Harvest any native plants that are to be replanted in the finished project and establish them in a suitable temporary location.

- Stockpile topsoil to be redistributed on finished grade.

- Where bank erosion presents an imminent threat to property and/or public safety, the use of temporary hardscape stabilization techniques may be required. A strategy should be developed for replacement of these techniques with a more ecologically appropriate technique when/if the imminent threat passes.

1.10.38 Techniques

On-site Retention and Treatment

One of the most effective ways to avoid the need for runoff control is the on-site retention and treatment of both storm and non-stormwater flows. The City's new Stormwater Management Plan (SMP) provides comprehensive direction for management of stormwater as well as a Minimum Control Measure (MCM) and Best Management Practices (BMPs) that specifically call for detection of and addressing non-stormwater discharges. The SMP further specifies that such discharges will be within the scope of the City's new Stormwater Ordinance. The treatment of stormwater and urban runoff through on-site methods not only reduces the quantity of untreated flow entering the creeks, but also provides potential for aquifer recharge.

Education and Outreach

Another method to reduce the need for runoff controls is to limit the amount and improve the quality of water coming into the creek corridor at its source by educating homeowners and commercial property managers on the impacts of landscape care products, over irrigation, hosing down sidewalks, car washing, etc. on stream systems. Golf course maintenance departments should have a program for integrated pest management that reduces the amount of pesticide and herbicide used on turf grass, and manages irrigation levels to avoid runoff.

Passive Treatment Systems and Detention Basins

Where stormwater from potentially polluting land uses such as roads, parking lots, railroads and heavy industry drains directly into the storm drainage system, vegetated swales, oil/water separator vaults and other techniques are used to capture and treat the runoff at the source. Since it is often the first flush from a storm event that carries the heaviest pollutant load, these systems should be designed to treat the first major incidence of rain. Passive treatment systems such as grassy swales, filtration wetlands, and detention ponds create habitat for wetland species in or near the riparian fringe. A combination of a settling pond and filtration/detention wetland is an effective means for polishing runoff coming from an outfall before discharge into a creek if adequate space is available in the floodplain terraces. Instead of discharging storm drain outfalls directly into the creeks, they are positioned to discharge parallel to the creek in the downstream direction. A wetland can be designed such that it expands the riparian habitat into the upper floodplain but gradually slopes down to the creek elevation so that discharged water does not cause increased erosion. The wetland plants supported by such a system can provide valuable habitat for both riparian and other species.

Bank Vegetation

At a minimum, all creek banks that convey sheet flow should be well vegetated with a diverse mix of grasses and forbs to reduce flow velocity and erosive force. Grassland buffers, which were once native in this area, help to reduce overland sheet flow by acting as a kind of filtration system. The roots help hold the soil in place while at the same time providing sub-surface biological activity that increases the porosity of the surface soil allowing for greater water infiltration. The additional infiltration reduces overland flow thereby removing a major erosion mechanism. Infiltrated water carries pollutants, such as excessive nutrients or hydrocarbons, and draws them in the soil where they are stored and eventually either absorbed by the grasses or broken down by microbial action. During larger storm events where the infiltration rate or capacity is exceeded, the above ground portion of the grasses create a kind of maze that surface water must move through, effectively increasing the total travel path, decreasing slope angles and velocities, and resulting in reduced erosion potential. Particulate matter can also adhere to the vegetation, thus creating a sort of filter effect that reduces the quantity of pollutants that reach the creek.

A mixture of grasses with woody shrubs and trees provides additional control for runoff since the larger plants can uptake and evapotranspire larger volumes of water, and their deeper roots help to intercept and retain some of the subsurface flow, and increase bank stability.

Erosion Protection on Adjacent Lands

Where unimproved stormwater or urban runoff is carried directly into the creek corridor via overland flow through adjacent fields and/or concentrated flow through small-eroded bare earth channels or unpaved trails, sediment can be transported directly into the creek. This impact can be controlled by revegetating denuded areas adjacent to the creek corridor with native grasses, sedges, and rushes. For unpaved trails, a series of water bars which divert water off the trail at controlled points can effectively eliminate erosion. Water bars need regular maintenance to ensure that excess soil and debris that may build up at the down slope end of the water bar are removed. Drainage dips are also effective in dissipating and diverting water flow across trail surfaces to prevent erosion. These, too, require maintenance to keep them unplugged.

1.11 Access Management

1.11.39 Benefits

Access management includes the provision of properly design access features sited in appropriate locations as well as the exclusion of activities that are detrimental to the creek corridor. Providing appropriate access will allow residents to safely recreate in the creek corridor, facilitate environmental education, and allow maintenance and emergency services the ability to effectively work in the corridor when necessary. Controlling detrimental access will reduce erosion, sedimentation, wildlife disturbance, the destruction of valuable riparian vegetation, homeowner concerns about privacy and safety, and vandalism.

1.11.40 Where Appropriate

Access management should be implemented where any of the following conditions exist:

- Informal, undesignated trails are becoming established by people trying to reach a destination within the creek corridor,
- Off road vehicles (ORVs) are being ridden in the creek corridor,
- Schools and parks are adjacent to the creek corridor,
- Scenic views or significant natural features provide opportunities for visual access,
- Additional access to the creek is desired and no controlled access means currently exists, or
- Private property is adjacent to the creek corridor.

1.11.41 General Practices

- Determine what level of access is required for a particular location based on habitat character and sensitivity, topography, safety, and connectivity to other access features.

- Identify who the anticipated users will be so access measures can be designed to accommodate the various abilities and modes of use.

- Select the technique(s) required for the desired access management. Several methods may be needed in combination to be most effective (such as bollards and signage.)

- Verify that the planned provision or restriction of access to public lands within the creek corridor is consistent with City ordinance.

- For access barriers, determine which uses are to be excluded and design barriers accordingly. For example, pedestrian access may be acceptable in certain preserve areas while bicycle access is not.

- For any constructed access amenities or barriers in the creek corridor, evaluate potential impacts to flood conveyance, hydrology, and habitat, and design appropriate mitigation measures.

- Design any constructed access amenities or barriers in the creek corridor to visually blend in with the natural character of the open space as much as possible.

- Include signage to indicate any access restrictions or regulations, and to remind people about what access controls are important to maintaining the health of the creek corridors.

- Provide public education about new access opportunities or access barriers as they are implemented.

- Provide adequate ordinance enforcement to make sure that access barriers are effective.

- Provide adequate maintenance so that access features are safe and attractive.

1.11.42 Techniques

Signage

Signage should provide directions, limitations of use, and interpretive information about the features of the creek corridor. In general, signage should have a similar style throughout the City's public open spaces so that the public readily recognizes the signs as conveying official City information. Opportunities for signage occur anywhere the public interfaces with the creek corridor such as along trails, at overlooks, parks, and at road crossings.

Bollard and Gates

Bollards, used separately or with gates, limit vehicular access, while allowing access for pedestrians and bicyclists. Bollards should be removable to allow access for emergency or maintenance vehicles.

Berms and Boulders

Access can be discouraged by building berms and/or situating large boulders across an informal access point. This method can provide effective access control and still blend in visually with the natural character of the corridor. Boulder groupings should include several sizes and should be placed in an informal arrangement to achieve a more naturalistic appearance. Berms should tie gradually into the existing grade and be vegetated with the same species as the surrounding landscape.

Vegetated Barriers

Certain types of plants, such as dense, woody shrubs or those with thorns, can provide effective access barriers once they are established. This approach to access management may also enhance habitat. It is important to protect the plants as they are becoming established and to use large enough plants for the barrier to be effective.

Designated Trails

Where creek bank stability, topography, habitat sensitivity, corridor width, and public safety allow, designated trails may be built to provide managed recreational access to the creek corridor for the public. Trails may be either paved or unimproved, depending on the character of the corridor, anticipated users, and connections to other elements of the City's trail system.

Open Fencing

In some locations, corridor conditions are not suitable for trails or overlooks. However, open fencing, such as wrought iron or split rail, may be used to preserve visual access to the corridor while excluding unsafe physical access.

Boardwalks

Boardwalks are similar to trails except that they are suspended on piers above the ground to preserve sensitive habitat and/or to allow water to flow underneath. Boardwalks may require side rails if they are elevated more than 30" above the ground or if they cross open water.

Viewing Platforms/Overlooks

Viewing platforms and overlooks are constructed to provide visual access to a scenic area while controlling the degree of physical access. They may include benches and interpretive signage, and should have rails if they extend out over open water or the creek bank.

Ordinance Enforcement

Regular patrols and oversight of the creek corridor are needed to ensure that access violations are prevented. The public can be a critical partner in this oversight by reporting access violations to the City for enforcement.